LEFT ABUTMENT LANDSLIDES
ANDERSON DAM

SANTA CLARA VALLEY WATER DISTRICT

April 1977 J B Scott

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SANTA CLARA VALLEY WATER DISTRICT

LEFT ABUTMENT LANDSLIDES
ANDERSON DAM

Office Report

BY

J. B. Scott
Engineering Geologist

April 1977

Introduction

Construction of Anderson Dam was completed in 1952. The first documented post-construction landslide in the left abutment area occurred in 1962. Since that time, additional sliding has occurred and property damage has been sustained. District geologists and personnel have monitored the slides since 1962. This report is a compilation of data gathered by District Geologists L. Page, J. Wire, J. Vantine, T. Iwamura, F. Fenzel, and J. Scott.

Discussion of Landslide Conditions

The left abutment area landslides condition at Anderson Dam has been of concern to the District since they could pose a threat to the intake structure in the upstream toe of the dam and/or could displace the boat launching ramp. These slides are designated as Slides A, B, and C (see Sheet 1).

Pre-construction landslide conditions in the left abutment area were noted by both Dr. George Louderbeck and Mr. Chester Marliave; they mentioned these conditions in their geologic reports of the damsite (1,2). Aerial photographs taken in 1960 indicate that slope failures had occurred in the area above the main scarp of the landslide between construction in 1952 and 1960. After the first major failure in 1962, active sliding has been more or less continuous to date. Two slope indicator (SI) holes were installed in 1972 (See Appendix 2 for logs, slope indicator readings and survey data). The slide area was mapped in some detail by Frank Fenzel in 1973. A very thorough discussion of the geologic conditions of the slide area, was prepared as an unissued draft report by Frank Fenzel, dated January 16, 1974. This draft report is placed in Appendix 3 as a reference. A geologic reconnaissance was made of the slide area in 1976 by J. Scott and a third SI hole (See Appendix 2) was installed in 1976. The surface elevation of this SI hole is about 60 feet below full reservoir level. Therefore, in some years readings will have to be taken when the SI hole is under water.

In summary, the geology of the immediate area is that of rock units intersected by the Coyote Creek Fault. Sheared and weathered serpentine are on the east side of the fault and Franciscan units of greenstone and shale-graywacke on the west side. Some of the rock units adjacent to the fault zone are intensely altered. Ancient landslide deposits and colluvium cover the formation units. In places the topography is very steep. The slide area consists of an ancient slide mass (Slide C) which has slides A and B within its boundaries.

Landslide A

This is the slide with the greatest potential for mass movement of a large volume of material. An engineering analysis was made of a deep arc failure of this slide. Using what are believed to be reasonable strength parameters, the slide with this type of failure is judged to be stable under all static conditions of normal reservoir operation except rapid drawdown or a seismic acceleration in excess of 0.05 g. See Appendix 1 for photographs. Shallower portions of Landslide A are not stable and some movement occurs each year, as indicated by SI-1A and surface expression as shown in photos 4 and 5, Appendix 1.

Accelerated movement of the shallow zone, while it will cause "unsightly" scars and put sediment into the reservoir, is not judged to be a hazard to either the intake works or boat ramp.

Landslide B

Portions of Landslide B, for the most part, have been removed by natural means (sliding). During construction of the dam, a "dumped" spoil zone was placed on what appeared to be competent material (see Photos 1 and 2, Appendix 1). The boat ramp and adjacent improvements were placed, in part, on this spoil material. Additional fill material was also placed when the boat ramp was constructed. Upon saturation and normal reservoir operation, failure started. It appears that only the fill and spoil material failed (see Photos 2 and 3, Appendix 1). Only remnants of the spoil zone remain and if additional failures do occur, it appears that the resulting debris will catch on the boat ramp or flattened portions of the slope below the ramp. Thus, the impact on the intake works should not be serious. Such a failure could affect some local portions of the boat ramp. No engineering analysis was made of this landslide zone.

Landslide C

This zone comprises the distinguishable limits of an ancient large landslide mass as defined by landslide deposits. The portion of the landslide zone east of the fault appears to be quite thick. The western portion of the slide, based on both SI hole data and surface expression, appears to be very shallow. Other than the active portions of this landslide, discussed above, the slide zone is judged to be relatively stable. However, very strong seismic shaking could result in movement of the entire slide mass, especially the thicker eastern portion of the slide. Such a failure could affect the boat ramp. It must be stated that while it is possible that the intake structure would also be affected, it is judged to be remote. No reasonable strength parameters are available by which an engineering analysis could be made of the slide zone, so none was made. However, it is judged that it would require at least a 0.1 g acceleration seismic event to cause failure.

	Reservoir Elevation	Steady Seepage	Ø	C	Seismic Acceleration	SF
Case I	625 (full)	X	19.6°	500#	0.00	1.55
	625	X	"	"	0.05	1.31
	625	X	"	"	0.10	1.14
Case II	564	X	"	"	0.00	1.17
	564	X	"	"	0.05	1.03
	564	X	"	"	0.10	0.92
Case III	536	X	"	"	0.00	1.01*

*Analysis was made by Ordinary Swedish Circle Method of slices allowing for seepage forces. Calculations were made on a HP-67 with a "in-house" program. Analysis was based on the assumption that with a reservoir elevation of 536 the SF is 1.01 (based on past history of slide during reservoir operation).

Configuration of the slide is based on surface exposure of the head scarp, intersection of the failure plane in Drill Hole SI-3, and a break in the surface which suggests the toe. Dry unit weights were estimated. Seepage forces and groundwater levels were estimated. For the mass to have an SF of 1.01 this required Ø = 19.6° and C = 500# values. Pseudo-static analyses were made for 0.05 and 0.10 g accelerations. (See Section A-A', Sheet 2).

For information purposes, what were considered possible, but not necessarily economically feasible, corrections or modifications were incorporated into the Case IV analysis to determine relative improvement in the SF.

Case IV- (Unloaded and install Drainage System - See Section A-A, Sheet 2) With Reservoir at Elevation 564 (Slow Drawdown)

Reservoir Elevation	Steady Seepage	Ø	C	Seismic Acceleration	SF
564	X	19.6°	500#	0.00	1.22
564	X	19.6°	500#	0.10	0.96
564	X	19.6°	500#	0.15	0.86

This included unloading about 50,000 yds from the top of the slide and drilling a 1200-foot system of drain holes that would allow more rapid lowering of seepage forces during drawdown of the reservoir (see Sheet 2). Using $2.25 per yard excavation and $12.00 per foot drilling, a cost of $130,000 is indicated. This only achieved a 0.05 improvement in the Factor of Safety.

Conclusions and Recommendations

1. Landslide A has the greatest potential to generate a large volume landslide. The movement of such material, however, should not affect the intake works but could damage the boat ramp.

2. Landslide B material, even though posed almost directly over the intake works, is not judged to be a serious hazard. This slide could affect local sections of the boat ramp.

3. Landslide C, while judged to be inactive, in the case of a strong seismic event could affect the boat ramp, and to a lessor degree the intake works.

4. Readings for SI-1A and SI-2 were taken thru 1976. Further readings for those holes are not recommended. Readings of SI-3 should be taken each year at a point when the reservoir level is the lowest.

5. Resloping and drainage for purposes of increasing the Factor of Safety is not recommended, because the potential hazard does not appear to warrant expending the funds required to achieve only a modest improvement in the SF. If an increase in the Factor of Safety is desired, the placement of a drainage system would be the most feasible.

7. Engineering analysis of the deep failure arc of Landslide A gave a 0.92 to 1.55 range in Factors of Safety.

References:

1. Marliave, C. (1945), "Geological Report on Anderson Damsite, Santa Clara County, California", unpublished report to the Santa Clara Valley Water Conservation District.

2. Louderback, G. D. (1950), "Report to the Santa Clara Valley Water Conservation District concerning Anderson Damsite", unpublished report.

PROJECT: Anderson Left abutment Slide (Deep Arc) **PROGRAM:** HP-67 (Swedish Circle-50 4/77) Section A-A' **DATE:** 4/12/77

Reservoir Elev. 625 Case I

1	2	3	4	5	6	7		8	9	10	11	12	13
γw= 62.4	Δy= 906	P1	P2	P3	P4	P5	φ	S1	S2	S3	S4	S5	
γd= 115	Δx= 327	y= 625	y= 625	y= 728	y=	y= 36	19.6°	y= 625	y= 625	y= 720	y=	y=	
γw1= 135	ΔR= 432	x= 104	x= 415	x= 741	x=	x=		x= 104	x= 415	x= 741	x=	x=	

	Pt.	y	x
P1 S1	1	539	104
	2	559	160
	3	567	190
	4	564	271
	5	576	292
	6	591	332
	7	602	373
	8	610	393
P2 S2	9	625 →	415
	10	640	432
	11	659	465
	12	664	485
	13	686	532
	14	710	567
	15	724	596
	16	731	634
	17	743	656
	18	747	673
	19	756	693
	20	772	720
P3 S3	21	789	741
	22		
	23		
	24		
	25		
	26		

	①			②	③	Accel 0.05 g.		Accel 0.10 g.	
Slice	α°	l1	u1	N1	T1	Ts	Ns	Ts	Ns
1	-26.83	6174	0	340320	-172153	-155137	348928	-138121	357535
2	-20.60	3184	0	233772	-87872	-76183	238166	-64495	242559
3	-12.91	8242	0	755046	-173034	-135282	763698	-97529	772349
4	-6.05	2109	0	213576	-22620	-11941	214707	-1262	215838
5	-1.99	4002	0	420562	-14612	6416	421293	27444	422023
6	3.38	4116	0	434547	25695	47422	433262	69150	431978
7	7.45	2020	0	208311	27233	37649	206949	48064	205588
8	10.27	2242	0	224787	40718	51957	222751	63197	220715
9	12.91	1748	221	181075	41497	50551	179000	59605	176925
10	16.33	3461	1693	383188	112325	131464	377573	150624	371958
11	20.03	2139	1838	235261	85791	97554	230971	109317	226682
12	24.84	5259	6729	539742	249892	276879	527247	303866	514753
13	31.00	4146	7209	396486	238238	258062	384574	277887	372662
14	36.09	3647	7394	315531	230043	245820	304029	261596	292527
15	41.81	5246	11638	348166	311410	328818	332596	346227	317025
16	47.40	3321	7748	161806	175970	184060	153008	192151	144209
17	51.38	2780	6495	104993	131406	136656	98423	141905	91852
18	55.49	3644	8208	97460	141777	146650	90371	151523	83282
19	61.46	6048	12052	89888	165268	169762	81625	174257	73361
20	69.07	6535	0	24853	64987	66230	21604	67472	18354
21						1857408	5630773	2142876	5194641
22	SF = 1.55								
23	Results Stored Card #2					SF = 1.31		SF = 1.14	
24									
25									

C = 500#

SUMMARY DATA:
Σ(N-u) =
Σ(T) =
Σ(L) =

Note: At full reservoir and using assumed and calculated values, the SF = 1.55. Seismic acceleration values of 0.05g gave SF = 1.31 and 0.10g gave SF = 1.14

$$SF = \frac{\Sigma(N-u)\tan\phi + cL}{\Sigma T}$$

PROJECT: Anderson Left Abutment Slide (Deep Arc) **PROGRAM:** HP-67 (Swedish Circle - So 4/77) Section A-A' **DATE:** 4/12/77
Reservoir Elev. 564 - Case II

1	2	3	4	5	6	7		8	9	10	11	12	13
γ_w=	Δy= 906	P_1	P_2	P_3	P_4	P_5	φ	S_1	S_2	S_3	S_4	S_5	
γ_d= 115	Δx= 327	y= 564	y= 564	y= 728	y=	y=	19.6	y= 564	y= 564	y= 720	y=	y=	
γ_{w_1}= 135	ΔR= 432	x= 104	x= 271	x= 741	x=	x=		x= 104	x= 271	x= 741	x=	x=	

	Pt.	y	x
$P_1 S_1$	1	539	104
	2	559	160
	3	567	190
$P_2 S_2$	4	564	271
	5	576	292
	6	591	332
	7	602	373
	8	610	393
	9	625	415
	10	640	432
	11	659	465
	12	664	485
	13	686	532
	14	710	567
	15	724	596
	16	731	634
	17	743	656
	18	747	673
	19	756	693
	20	772	720
$P_3 S_3$	21	789	741
	22		
	23		
	24		
	25		
	26		

				②	③	Accel 0.05 g.		Accel 0.10 g.	
Slice	α°	l_1	u_1	N_1	T_1	T_s	N_s	T_s	N_s
1 -	26.83			150113	-75936				
2 -	20.60			126881	-47693				
3 -	12.91			466930	-107006				
4 -	6.05			144131	-15265				
5 -	1.99			327026	-11362				
6	3.38			371215	21950				
7	7.45			188856	24690				
8	10.27			223243	40439				
9	12.91			190110	43568				
10	16.33			399096	116967				
11	20.03			243845	88921				
12	24.84			556772	257776				
13	31.00			406352	244166				
14	36.09			321949	234723				
15	41.81			354295	316891				
16	47.40			164261	178640				
17	51.38			106388	133151				
18	55.49			98589	143419				
19	61.46			90652	166673				
20	69.07			24853	64987				
21	SF = 1.17					2067477	4864574	2315255	4773587
22	Results Stored Card #3					SF = 1.03		SF = 0.92	
23									
24									
25									

C = 500#

SUMMARY DATA:
Σ(N-u)=
Σ(T) =
Σ(L) =

Note: At Reservoir Elev 564 and using assumed and calculated values, the SF = 1.17. Seismic acceleration values of 0.05g gave 1.03 SF and 0.1 g gave 0.92 SF.

$$SF = \frac{\Sigma(N-u)\tan\phi + cl}{\Sigma T}$$

PROJECT: Anderson Left Abutment Slide (Deep Arc) **PROGRAM:** HP-67 (Swedish Circle – 50 4/77) Section A–A' Reservoir Elev. 536 – Slow drawdown. Existing slope **DATE:** 4/12/77 Case III

1	2	3	4	5	6	7		8	9	10	11	12	13
γw= 62.4	Δy= 906	P1	P2	P3	P4	P5	φ	S1	S2	S3	S4	S5	
γd= 115	Δx= 327	y= 536	y= 730	y=	y=	y=	25°	y= 536	y= 536	y= 720	y=	y=	
γw1= 135	ΔR= 432	x= 104	x= 741	x=	x=	x=		x= 104	x= 271	x= 741	x=	x=	

	Pt.	y	x
S1 —	1	536	104
	2	559	160
	3	567	190
S2 —	4	564	271
	5	576	292
	6	591	332
	7	602	373
	8	610	393
	9	625	415
	10	640	432
	11	659	465
	12	664	485
*	13	686	532
	14	710	567
	15	724	596
	16	731	634
	17	743	656
	18	747	673
	19	756	693
	20	772	720
S3 —	21	789	741
	22		
	23		
	24		
	25		
	26		

	①	⑤	④	②	③	Accel 0.05 g.		Accel 0.1 g.		C = 500#
Slice	α°	l_1	u_1	N_1	T_1	T_s	N_s	T_s	N_s	
1	−26.83	61.74	29798	122264	−61848					1
2	−20.60	31.84	40479	157277	−59119					2
3	−12.91	82,42	194725	560663	−128487					3
4	−6.05	21,09	65451	168370	−17833					4
5	−1.99	4002	118050	370345	−12867					5
6	3.38	4116	111994	411380	24325					6
7	7.45	2020	51322	206790	27034					7
8	10.27	2242	53948	241671	43777					8
9	12.91	1748	39889	203399	46613					9
10	16.33	3461	72955	422493	123825					10
11	20.03	2139	41340	256470	93524					11
12	24.84	5259	88608	581820	269373					12
13	31.00	4146	58200	420864	252886					13
14	36.09	3647	43189	331390	241606					14
15	41.81	5246	49686	363310	324954					15
16	47.40	3321	25185	167872	182567					16
17	51.38	2780	17663	108438	135717					17
18	55.49	3644	18773	100249	145834					18
19	61.46	6048	21901	91776	168740					19
20	69.07	6535	0000	24853	64987					20
21										21
22	SF = 1.26 at φ = 25°, C = 500#				SF = 1.01	φ = 19.6°		C = 500#		22
23	Results stored Card *1									23
24										24
25										25

SUMMARY DATA:

Σ (N-u)=

Σ (T) =

Σ (L) =

Note: Density, C, and seepage force lines were estimated. Based on operation history of Reservoir and periods of full draw down, it was estimated that lowest SF = 1.01. Using this data, φ calculated to 19.6° which seemed reasonable the values φ = 19.6° and C = 500#/ft² will be used for all other cases analyzed.

$$SF = \frac{\Sigma(N-u)\tan\phi + cl}{\Sigma T}$$

PROJECT: Anderson Left Abutment Slide (Deep Arc) **PROGRAM:** HP-67 (Swedish Circle - So 4/77) Section A-A' **DATE:** 4/12/77

Reservoir Elev. 564 with unloading of head and drain system - Case IV

1	2	3	4	5	6	7		8	9	10	11	12
γ_w=	Δy= 906	P_1	P_2	P_3	P_4	P_5	ϕ	S_1	S_2	S_3	S_4	S_5
γ_d= 115	Δx= 327	y= 564	y= 564	y= 633	y= 728	y=	19.6°	y= 564	y= 564	y= 633	y= 728	y=
γ_{w1}= 135	ΔR= 432	x= 104	x= 271	x= 567	x= 741	x=		x= 104	x= 271	x= 567	x= 741	x=

	Pt.	y	x
$P_1 S_1$	1	539	104
	2	559	160
	3	567	190
$P_2 S_2$	4	564	271
	5	576	292
	6	591	332
	7	602	373
	8	610	393
	9	625	415
	10	640	432
	11	659	465
	12	664	485
	13	686	532
$P_3 S_3$	14	697	567
$P_4 S_4$	15	747	741

500#

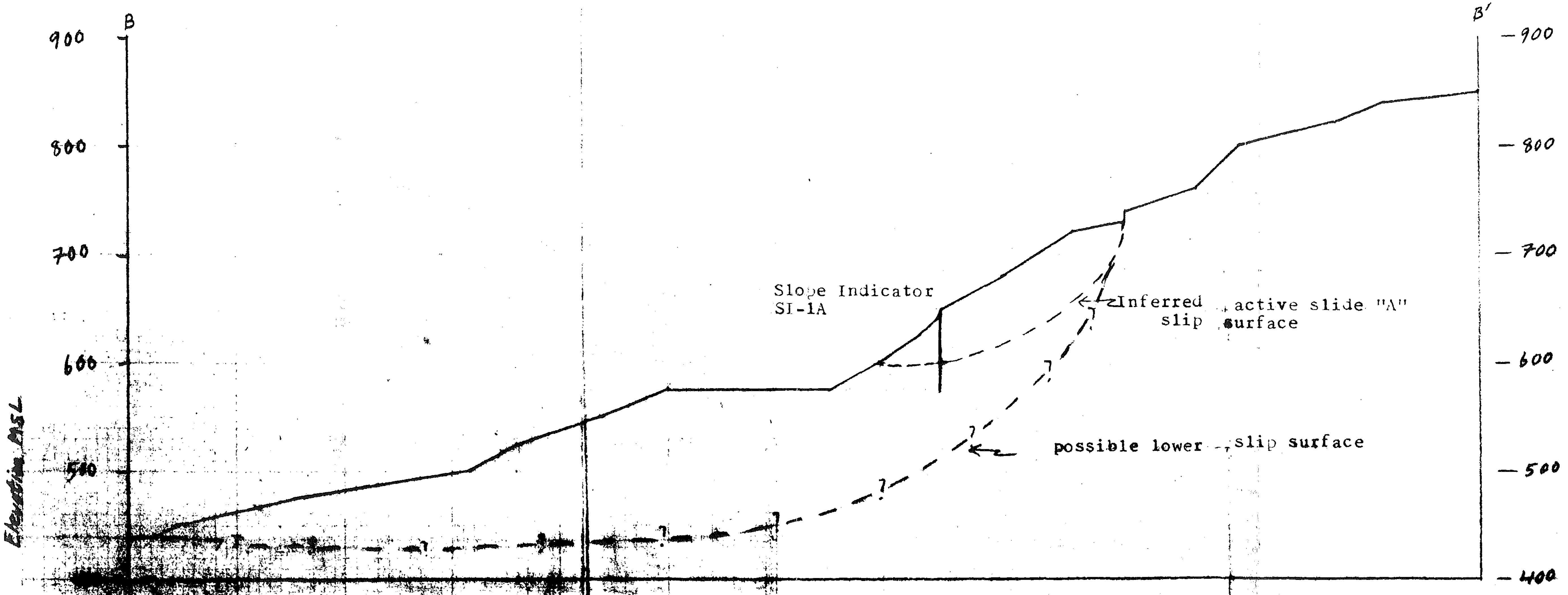
	①			②	③	Accel 0.1 g.		Accel 0.15 g.	
Slice	α°	l_1	u_1	N_1	T_1	T_s	N_s	T_s	N_s
1				150 113	- 75 935				
2				126 881	- 47 693				
3				466 930	- 107 006				
4				145 050	- 15 363				
5				333 893	- 11 601				
6				385 190	22 777				
7				198 162	25 906				
8				235 305	42 623				
9				200 697	45 994				
10				422 645	123 869				
11				259 903	94 776				
12				599 209	277 424				
13				418 930	251 724				
14	49.20	373.88		1 011 569	1 171 730				
15						2294673	4774555	2542397	4684 593
16	SF = 1.22								
17	Results stored Card #4					SF 0.96		SF 0.86	

SUMMARY DATA:
Σ(N-u)=
Σ(T) =
Σ(L) =

Note: At Reservoir Elev 564 with unloading and drain system (See Sheet 2) and using assumed and calculated values, the SF = 1.22. Seismic acceleration values of 0.1g gave 0.96 SF and 0.15g gave 0.86 SF.

$$SF = \frac{\Sigma(N-u)\tan\phi + cl}{\Sigma|T|}$$

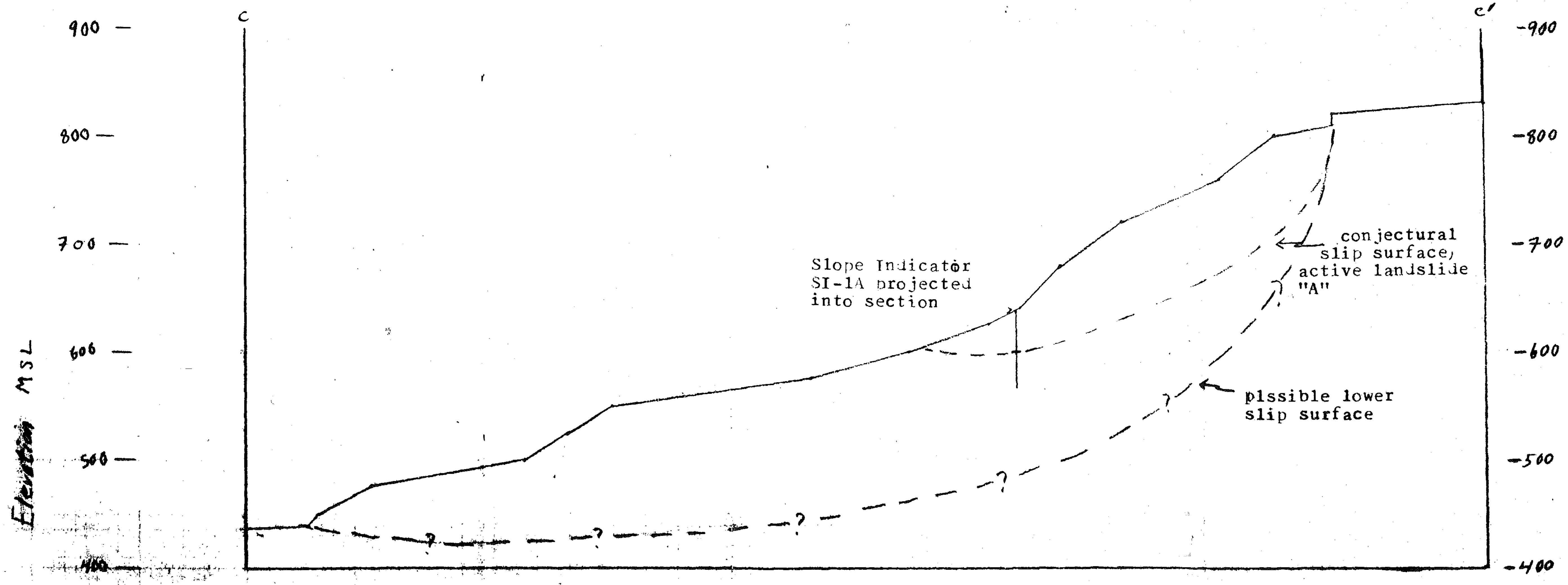
Figure__
Profile through
Landslide "A"
Cros section B-B'



SCALE 1" = 100' HORIZONTAL AND VERTICAL

F.W.F. January 4, 1974

Figure__
Profile through
Landslide "A"
cross section C-C'



SCALE 1" = 100' HORIZONTAL AND VERTICAL

F.W.F. January 4, 1974

REFER TO TRACING FOR LATEST REVISION

REV.	DESCRIPTION	SUB.	APPR.

REFERENCE INFORMATION AND NOTES

sp = SERPENTINE
fs = SHALE-GRAYWACKE
fg = GREENSTONE
▬ ▬ FAULT

▨ AREA BEYOND LIMITS OF LANDSLIDE A THAT WOULD REQUIRE RESLOPING IF PROPOSED LANDSLIDE CORRECTION WORK (UNLOADING) WAS PERFORMED.

DATE 4-1-77
DESIGN J. Scott
DRAWN L. Hill
CHECKED

Santa Clara Valley Water District

ENGINEERING CERTIFICATION
PROJECT ENGINEER
DIVISION ENGINEER R.C.E. NO. 15851

ENGINEERING APPROVAL
HEAD, DESIGN BRANCH R.C.E. NO. 4455

PLAN OF
LEFT ABUTMENT LANDSLIDE
ANDERSON RESERVOIR

SCALE 1" = 50'
SHEET 1

CASE I - ELEV. 625' (FULL RESERVOIR) STATIC, ACCEL. 0.0g, 0.05g and 0.10g
CASE II - ELEV. 564', STEADY SEEPAGE, ACCEL. 0.0g, 0.05g, and 0.10g
CASE III - ELEV. 536', STEADY SEEPAGE, ACCEL. 0.0g.

SAFETY FACTOR DATA

	0.0g	0.05g	0.10g	0.15g
CASE I	1.55	1.31	1.14	—
CASE II	1.17	1.03	0.92	—
CASE III	1.01	—	—	—
CASE IV	1.22	—	0.96	0.86

CASE IV (UNLOADED AND SUBSURFACE DRAINAGE), STEADY SEEPAGE,
ACCEL. 0.0g, 0.10 g., 0.15 g

REFER TO TRACING FOR LATEST REVISION

REV.	DESCRIPTION	SUB.	APPR.

REFERENCE INFORMATION AND NOTES

DATE
March, 1977
DESIGN
Jim Scott
DRAWN
Levi Hill
CHECKED

Santa Clara Valley Water District

ENGINEERING CERTIFICATION
PROJECT ENGINEER
DIVISION ENGINEER R.C.E. NO. 15851

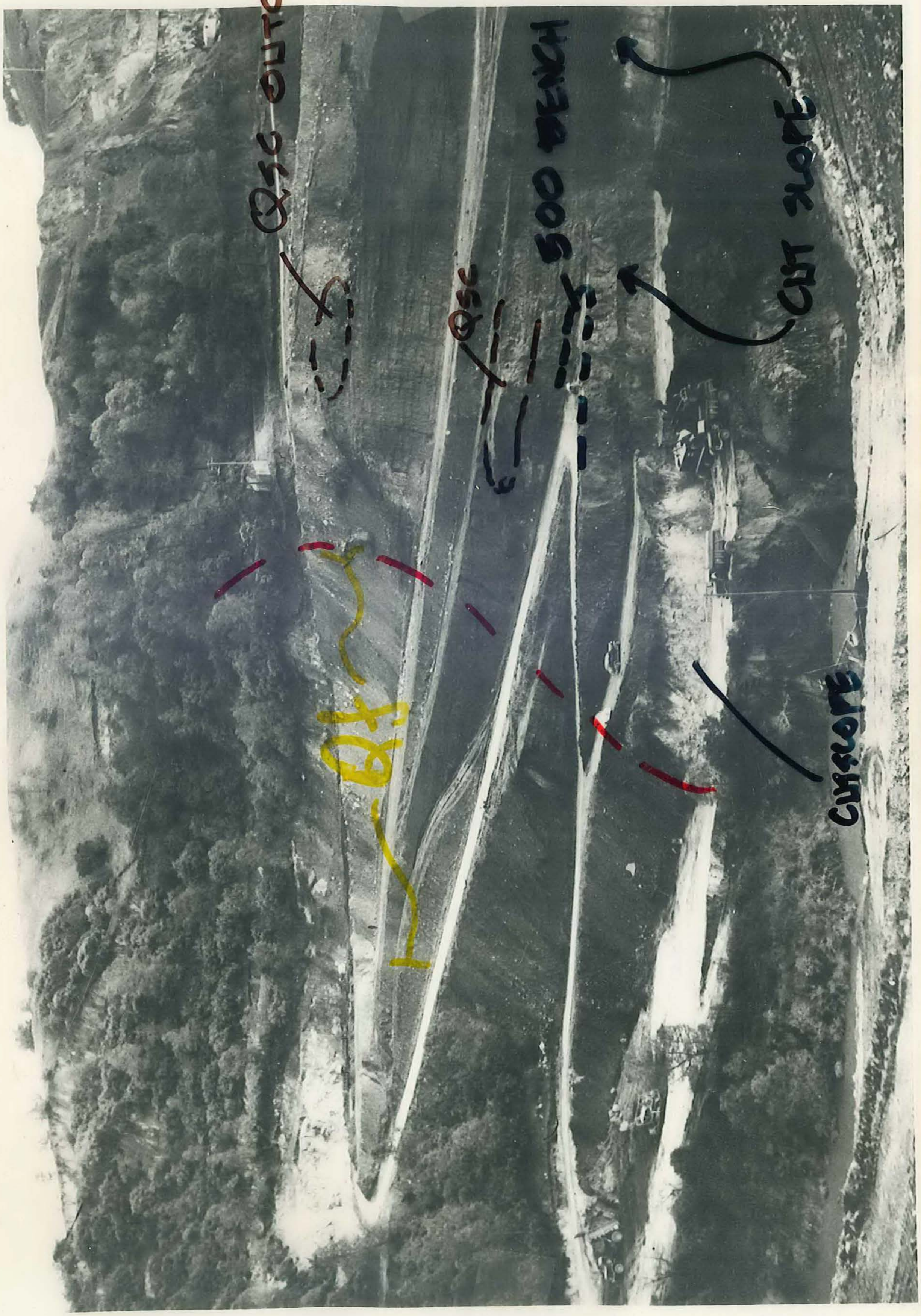
ENGINEERING APPROVAL
HEAD. DESIGN BRANCH R.C.E. NO. 14455

SECTION A-A'
OF A PORTION OF LEFT ABUTMENT LANDSLIDE
ANDERSON RESERVOIR

SCALE
1" = 40'
SHEET
2

APPENDIX 1

Photo 1 - View looking south toward left abutment landslide area during construction (1952). Note locations of fill material and shovel "teeth" marks in cut slopes.



1952

(OVERLAY ADDED 1987 BY A. BUANGAN OF WAHLER ASSOCIATES FOR INLET WORKS MODIFICATION STUDIES)

Photo 1 - View looking south toward left abutment landslide area during construction (1952). Note locations of fill material and shovel "teeth" marks in cut slopes.

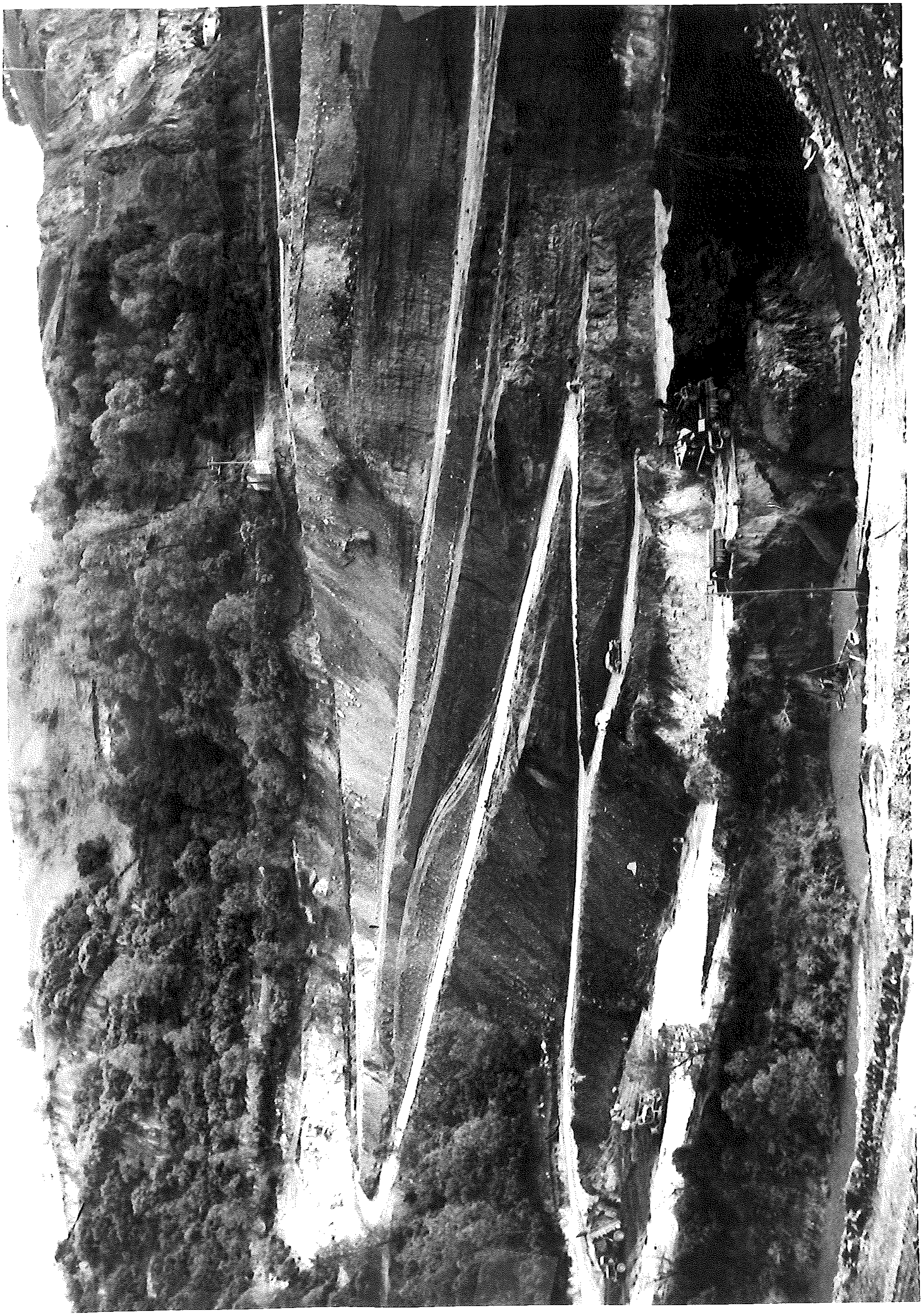
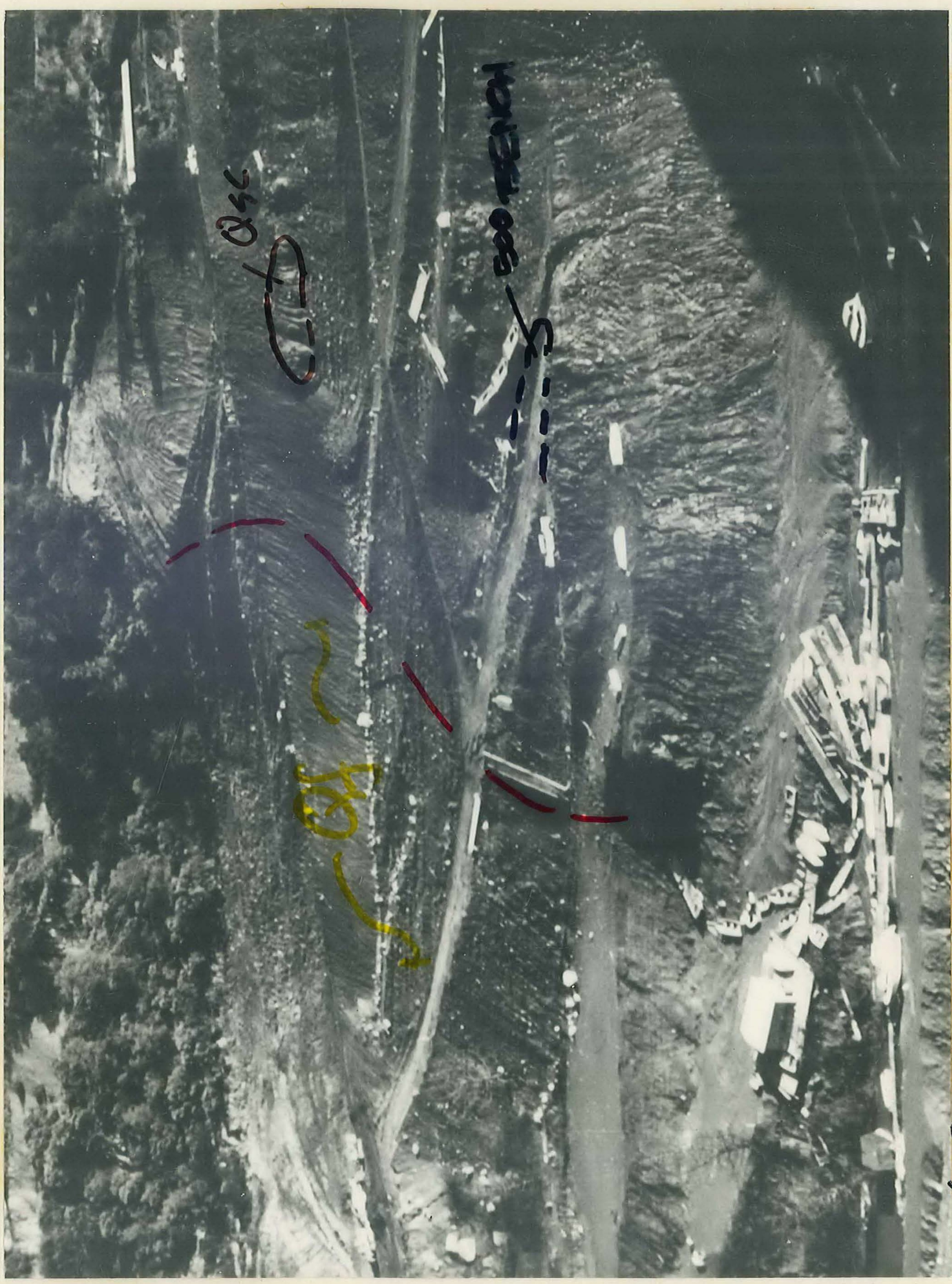


Photo 2 - View looking south toward left abutment landslide area during landslide repair work in 1962. Note where the "fill" material has failed. See "teeth" marks still showing in some cut slopes.

1960



(OVERLAY ADDED IN 1987 BY A. BUANGAN OF WAHLER ASSOCIATES FOR INLET WORKS MODIFICATION STUDIES)

Photo 2 - View looking south toward left abutment landslide area during landslide repair work in 1962. Note where the "fill" material has failed. See "teeth" marks still showing in some cut slopes.

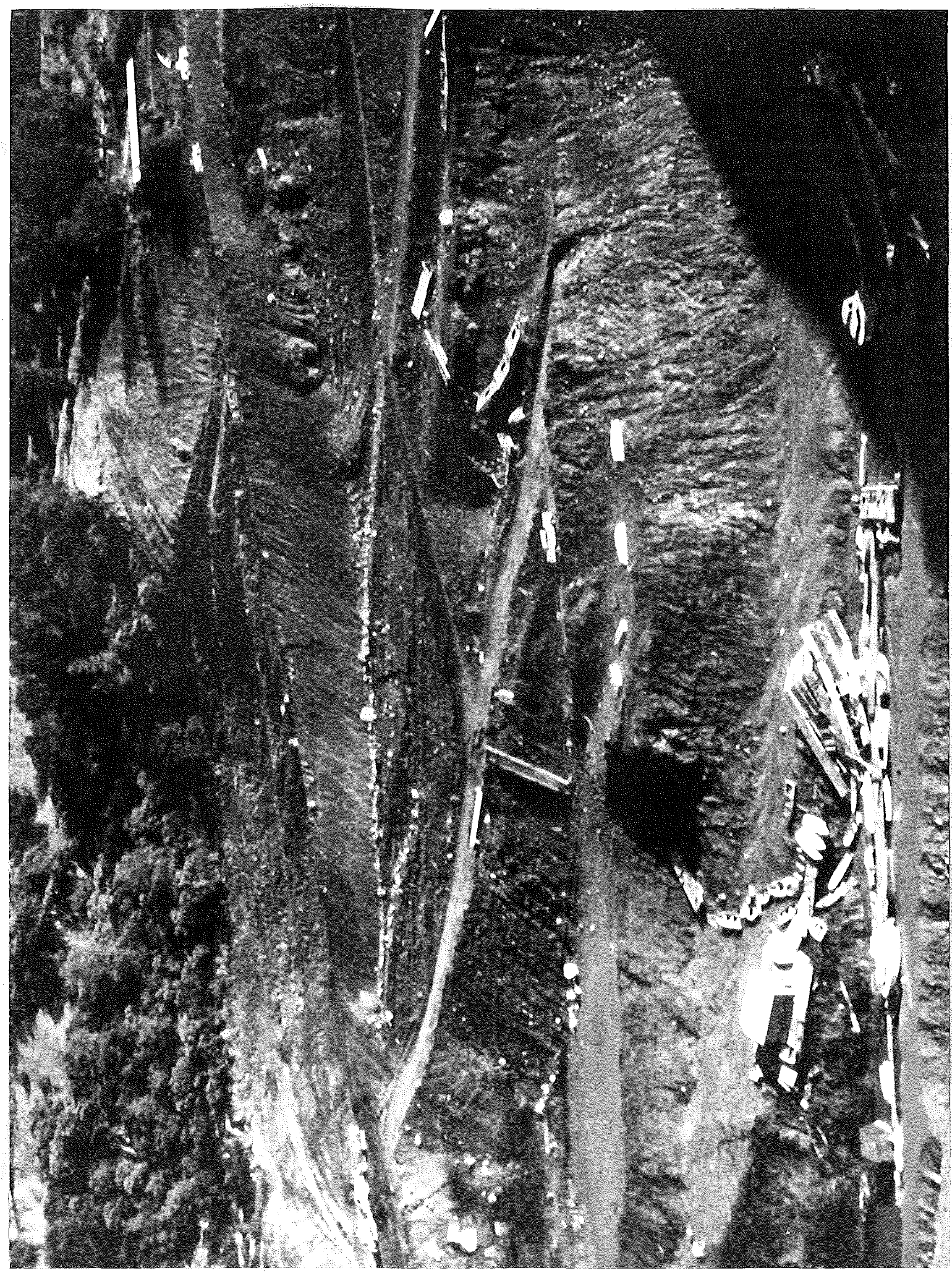


Photo 3 - View from dam toward left abutment landslide area (1963). Note failure in the "fill" material.

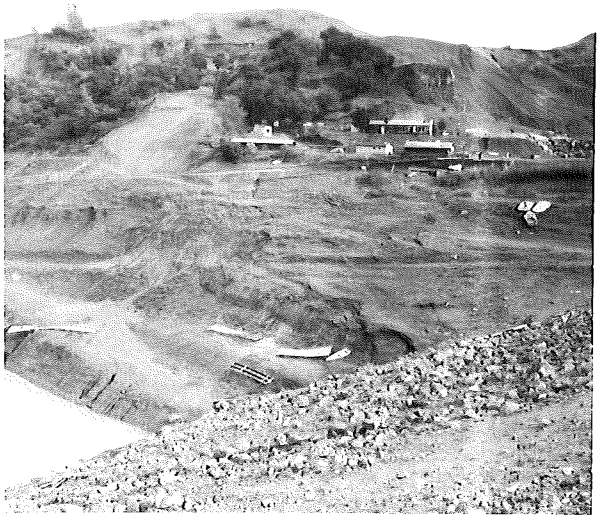
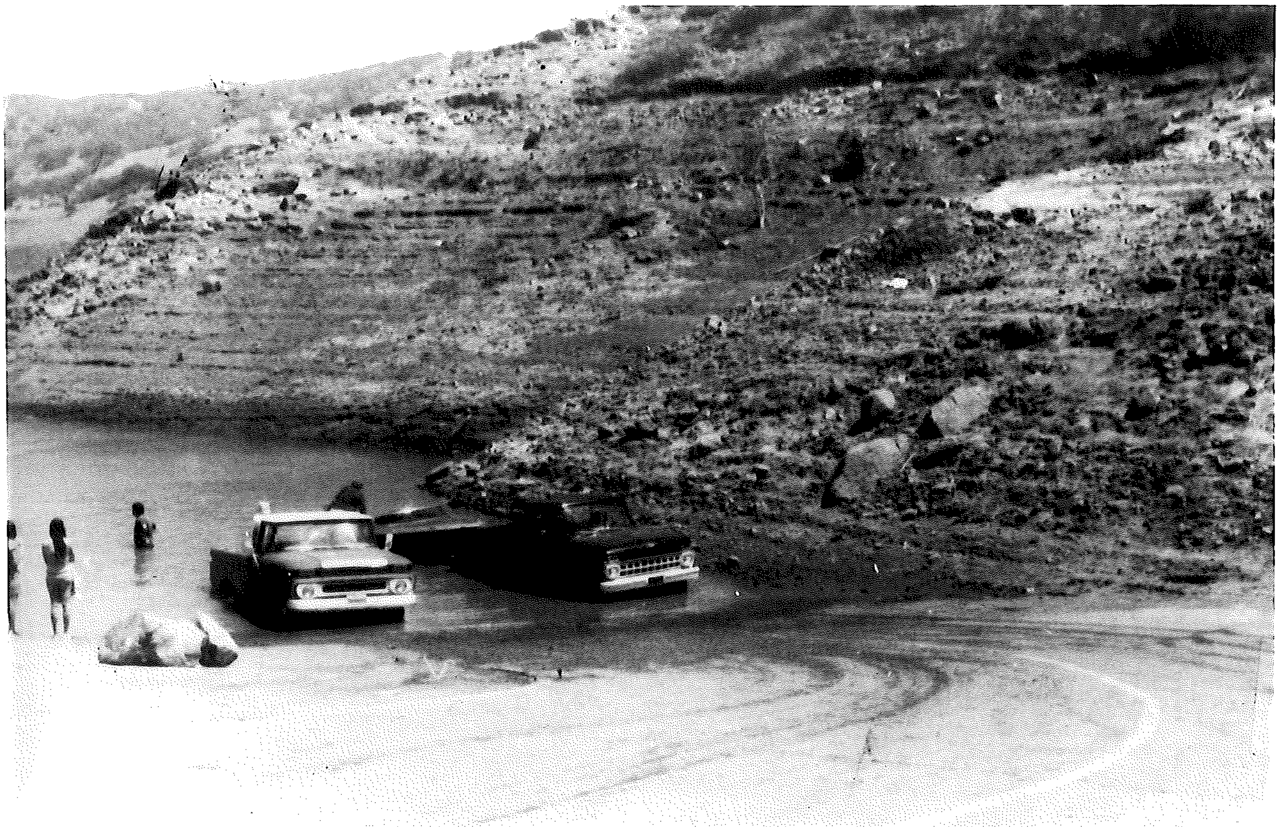


Photo 4 - View looking at Landslide A, taken in 1972. Water elevation 567 feet. Reference is made to large boulders right of pick-up. The slope is smooth and even.



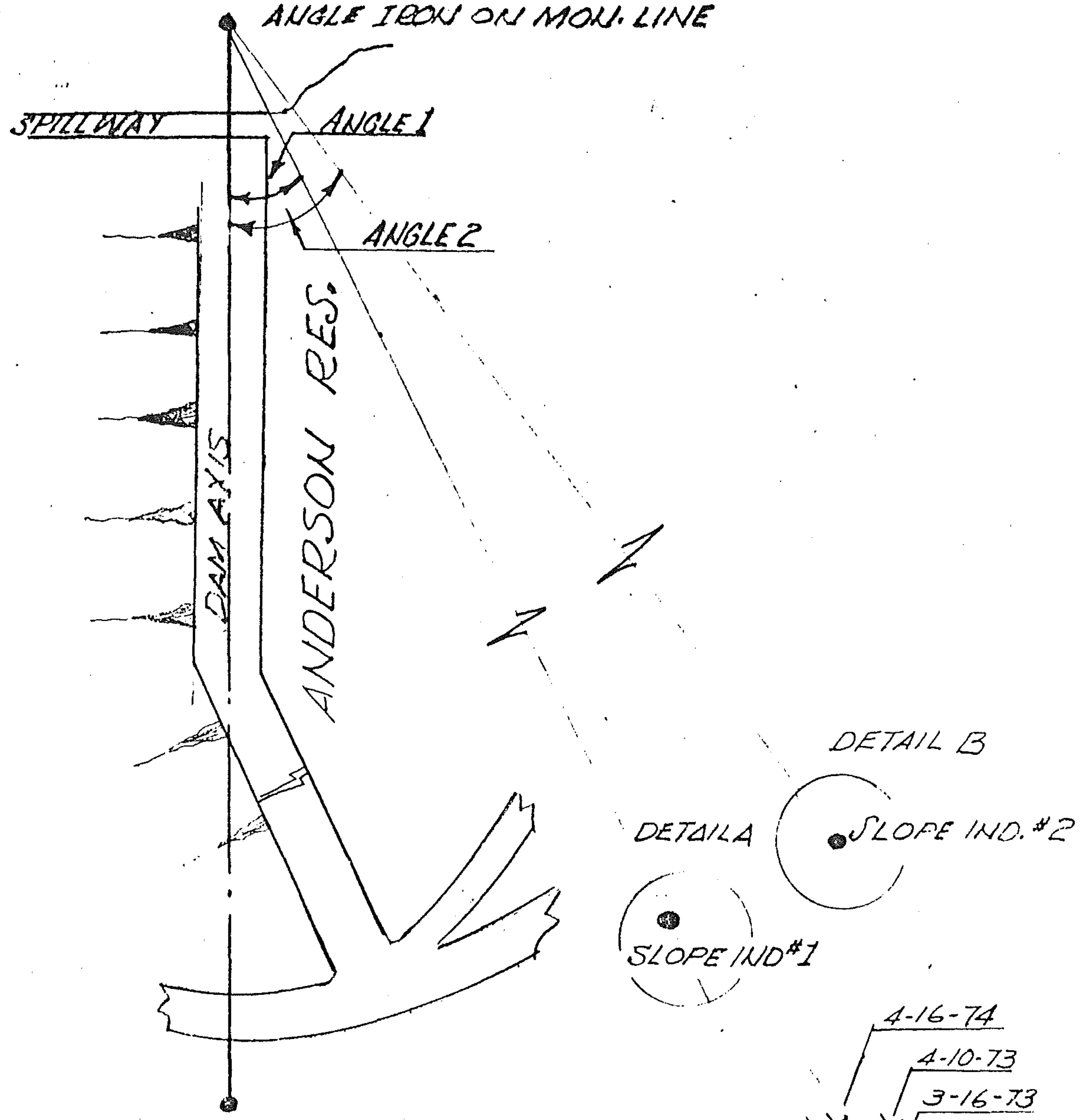
APPENDIX 2

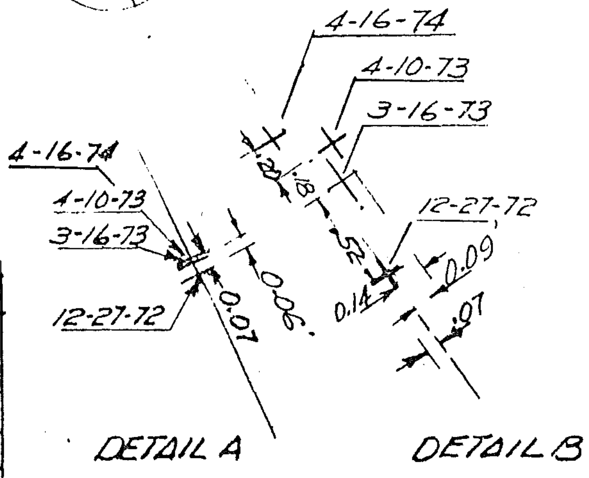
P-1

SANTA CLARA CO[illegible]TY FLOOD CO[illegible]TROL AND WATE[illegible]STRICT, San Jose, California

By ______ Date ______ Chkd. By ______ Date ______ Sheet No. ______ of ______

Subject MONITORING OF SLOPE INDIC. ANDERSON RES. Job No. ______





	SL. IND. #1		SL. IND. #2	
	DIST.	ANGLE 1	DIST.	ANGLE 2
12-27-72	1897.71	26-27-15	1991.75	37-55-19
3-16-73	1897.65	26-27-16	1991.23	37-55-28
4-10-73	1897.64	26-27-17	1991.05	37-55-33
4-16-74	1897.56	26-27-17	1990.85	37-55-12
4-15-76	1897.44		1990.44	

NOTE: DIST. SHOWN ARE SLOPE DIST.

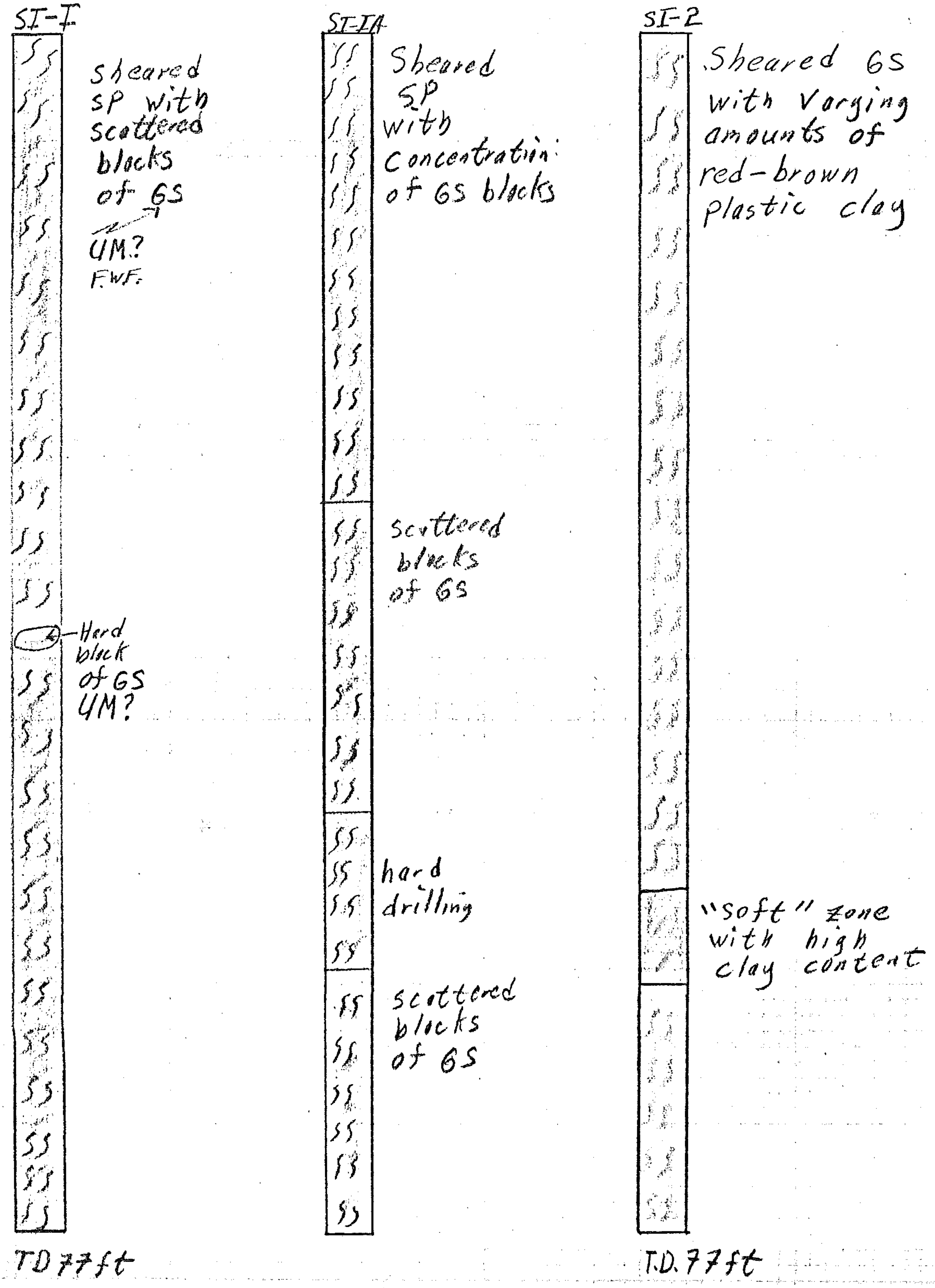
P-1

SANTA CLARA COUNTY FLOOD CONTROL AND WATER DISTRICT, San Jose, California

By F.W.F. Date 13/Dec/77 Chkd. By ____ Date ____ Sheet No. ____ of ____

Subject Log of Inclinometer Holes Job No. Figure 5

Left abutment, Anderson Dam; Loged by S;W


SI-I
Sheared SP with scattered blocks of GS
UM?
F.W.F.
Hard block of GS
UM?
TD 77 ft
SI-IA
Sheared SP with concentration of GS blocks
scattered blocks of GS
hard drilling
scattered blocks of GS
SI-2
Sheared GS with Varying amounts of red-brown plastic clay
"soft" zone with high clay content
T.D. 77 ft

SANTA CLARA COUNTY FLOOD CONTROL AND WATER DISTRICT

DRILLING AND SAMPLING LOG

Anderson Reservoir

HOLE NO. SI-3

ELEV.

FEATURE Left Abutment Landslide

DEPTH 92.0

LOCATION End of Boat Ramp -

COUNTY

LOGGED BY JBS

DATE DRILLED 10/25-26/76

WATER LEVEL —

DRILLING CO. Pitcher

DRILLER —

DRILL RIG Failing

Logging was done by inspection of cuttings.

ELEV. (DEPTH)	CLASS.	DESCRIPTION	SAMPLE NUMBER	MODE	REMARKS
		0-7.0, slide mass material. Frags and cobble size sp in matrix of CL (sandy clay), greenish brown.		R/D 5 7/8" Tricone	Shift started 8:00 A. Travel to site 2½ hrs. Set up rig and started drilling 12:15 P.
5.0					Some "clatter"
		7-11, Clay (CL) with pea gravel size rounded frags of sp, tan, altered zone, appears to be failure zone.	Failure Zone ?		Smooth drilling
10.0					Installed 6" casing to 10½ feet.
		11-30, slide mass material. Frags and cobble size weathered sp in matrix of CL (sandy clay), brown changing to green at 15'.			Making heavy mud, Had to thin. Hole is squeezing at 10'.
15.0					
20.0					
					21.5' at 2:15 PM
25.0		Becoming more silty at 25'			Heavy mud, have to thin every 5'
30.0					

SHEET 1 OF 3

SHEET 2 OF 3

ELEV. (DEPTH)	CLASS.	DESCRIPTION	SAMPLE NUMBER	MODE	REMARKS
30.0		30 - 42, slide mass material, soft frags of sp (green & black) in matrix of clayey sandy silt (ML), blue.		RD	
					Bad "chatter" at 34'
35.0					Mud starting to thin,
40.0					
		42 - 83, slide mass material, random frags of sp in matrix of clayey sandy silt - some zones of sand, blue.			Drilling rate is faster. Mud is getting thinner
45.0					
50.0					
55.0					
60.0					
					63.5' at 5:10 PM
65.0					
70.0					
75.0					

SHEET 3 OF 3

ELEV. (DEPTH)	CLASS.	DESCRIPTION	SAMPLE NUMBER	MODE	REMARKS
75.0		42-83, continued.		RD	
80.0					
		83-85, Clay zone, blue-grey.	Failure Zone		Clay zone at 8 PM
85.0		85-92, Formation, weathered to 86, then becomes very hard. Chips of quartz, black sp.			Very slow drilling.
90.0					
		Bottom Hole 92.0			
92.0		Installed SI casing and cemented. Installed cap and cleaned up site. Drill rig pulled out 11AM			Bottom at 1 AM

C-320-03

SHANNON & WILSON, INC.
Geotechnical Consultants
1550 Rollins Road • Suite F • Burlingame, California 94010 • Telephone: (415) 697-7563

May 7, 1976

Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, CA 95113

Attention: Mr. Tom Iwamura
Engineering Geologist

INCLINOMETER READINGS
ANDERSON DAM

At your request, data from Inclinometer Casings SI-1A and SI-2 were obtained on April 29, 1976. This set of readings was obtained in accordance with the terms of our agreement, Purchase Order No. 10914, dated November 24, 1975, to obtain two sets of readings, one in the early winter 1975 and one set in late spring 1976.

The locations of the Slope Indicator casings are shown in Fig. 1. Plots of lateral movements versus depth for Casing SI-2 are enclosed as Fig. 8 and 9. The calculator printout sheets showing initial and current differences and actual inches of lateral deflection are also enclosed. The observed deflections have not changed significantly from those observed in December 1974.

Inclinometer Casing SI-1A remains so deformed by movement that the instrument would not proceed past a depth of 45.8 feet. In our report of March 20, 1973, we reported a movement at the top of SI-1A in the order of eight inches in the north direction. The north-south deflection relative to the 46-foot depth has been computed and plotted in Fig. 10. The shape of the lateral movement versus depth curve for the current readings is approximately the same as for the March 1973 readings above a depth of 46 feet. Some further movement appears to have occurred above a depth of 46 feet since December 1974. The data relative to a depth of 46 feet is tabulated on Sheets 1 and 2 of 4. The deflection relative to the bottom is not known.

Water levels were observed at a depth of 25 feet in SI-1A and at 49 feet in SI-2.

May 7, 1976

Santa Clara Valley Water District
Attention: Mr. Tom Iwamura
Page two

Please do not hesitate to contact us if you have any questions or require further information.

Rudy J. Dietrich

Rudy J. Dietrich, P.E. by JKL
Senior Vice President

dmh

Enclosures: Inclinometer Readings
Figures 1, 8, 9, and 10

Sheet 1 of 4
Date of Readings
4-29-76

SLOPE INDICATOR DATA

PROJECT: ANDERSON RESERVIOR

SANTA CLARA COUNTY FLOOD CONTROL & WATER DISTRICT

OBSERVATION WELL NO. SI-1A

Depth Ft.	Initial Diff.	N+	S-	Diff.	Change	Def'l. In.
1.0	-86	525	587	-62	24	2.93
2.5	-82	524	589	-65	17	2.82
4.0	-81	526	589	-63	18	2.74
6.0	-134	508	609	-101	33	2.64
8.0	-135	484	630	-146	-11	2.44
10.0	-136	484	631	-147	-11	2.50
12.0	-141	483	630	-147	-6	2.57
14.0	-145	484	631	-147	-2	2.61
16.0	-191	471	645	-174	17	2.62
18.0	-194	466	649	-183	11	2.52
20.0	-198	462	652	-190	8	2.45
22.0	-201	460	655	-195	6	2.40
24.0	-203	457	657	-200	3	2.37
26.0	-247	448	668	-220	27	2.35
28.0	-252	436	678	-242	10	2.19
30.0	-255	434	678	-244	11	2.13
32.0	-260	434	680	-246	14	2.06
34.0	-261	434	679	-245	16	1.98
36.0	-318	427	687	-260	58	1.88
38.0	-326	429	687	-258	68	1.53
40.0	-332	423	691	-268	64	1.12
42.0	-320	408	707	-299	21	.74
44.0	-311	403	710	-307	4	.61
46.0	-357	479	638	-159	198	.59

Note: Casing deflection in inches as shown is not relative to initial location of the bottom of casing and reflects only a portion of the total deflection.

Instrument would not decend below a depth of 46 feet.

Sheet 2 of 4
Date of Readings
4-29-76

SLOPE INDICATOR DATA

PROJECT: ANDERSON RESERVIOR

SANTA CLARA COUNTY FLOOD CONTROL & WATER DISTRICT

OBSERVATION WELL NO. SI-1A

Depth Ft.	Initial Diff.	E+	W-	Diff.	Change	Def'l. In.
1.0	82	600	512	88	6	1.13
2.5	85	602	512	90	5	1.16
4.0	87	602	511	91	4	-1.18
6.0	169	622	497	125	-44	-1.21
8.0	175	636	480	156	-19	-.94
10.0	177	638	477	161	-16	-.83
12.0	177	639	475	164	-13	-.73
14.0	177	641	473	168	-9	-.66
16.0	175	640	473	167	-8	-.60
18.0	172	641	471	170	-2	-.55
20.0	169	638	475	163	-6	-.54
22.0	165	637	477	160	-5	-.51
24.0	163	635	480	155	-8	-.48
26.0	113	618	498	120	7	-.43
28.0	107	609	505	104	-3	-.47
30.0	103	608	507	101	-2	-.45
32.0	98	608	509	99	1	-.44
34.0	91	607	510	97	6	-.45
36.0	78	596	517	79	1	-.48
38.0	74	585	532	53	-21	-.49
40.0	72	579	533	46	-26	-.36
42.0	72	586	528	58	-14	-.21
44.0	81	589	527	62	-19	-.12
46.0	16	565	553	12	-4	-.01

See note on sheet 1.

Sheet 3 of 4
Date of Readings
4-29-76

SLOPE INDICATOR DATA

PROJECT: ANDERSON RESERVIOR

SANTA CLARA COUNTY FLOOD CONTROL & WATER DISTRICT

OBSERVATION WELL NO. SI-2

Depth Ft.	Initial Diff.	N+	S-	Diff.	Change	Def'l. In.
1.0	29	566	533	33	4	1.79
2.5	30	566	539	27	-3	1.78
4.0	33	572	540	32	-1	1.79
6.0	88	595	511	84	-4	1.80
8.0	88	640	470	170	82	1.82
10.0	88	653	457	196	108	1.33
12.0	86	628	480	148	62	.68
14.0	87	606	502	104	17	.31
16.0	47	587	521	66	19	.21
18.0	47	578	533	45	-2	.09
20.0	47	580	533	47		.10
22.0	47	579	532	47		.10
24.0	45	580	532	48	3	.10
26.0	47	579	531	48	1	.09
28.0	47	579	532	47		.08
30.0	58	583	528	55	-3	.08
32.0	54	583	526	57	3	.10
34.0	54	583	529	54		.08
36.0	65	586	526	60	-5	.08
38.0	64	588	523	65	1	.11
40.0	64	587	523	64		.10
42.0	62	587	523	64	2	.10
44.0	63	586	524	62	-1	.09
46.0	64	590	517	73	9	.10
48.0	64	587	523	64		.04
50.0	67	587	521	66	-1	.04
52.0	63	586	522	64	1	.05
54.0	61	584	522	62	1	.04
56.0	66	584	526	58	-8	.04
58.0	65	587	522	65		.09
60.0	64	587	522	65	1	.09
62.0	61	586	525	61		.08
64.0	63	586	526	60	-3	.08
66.0	40	587	523	64	24	.10
68.0	40	576	536	40		-.04
70.0	46	575	536	39	-7	-.04
72.0	46	578	533	45	-1	.00
74.0	44	578	532	46	2	.00

Sheet 4 of 4
Date of Readings
4-29-76

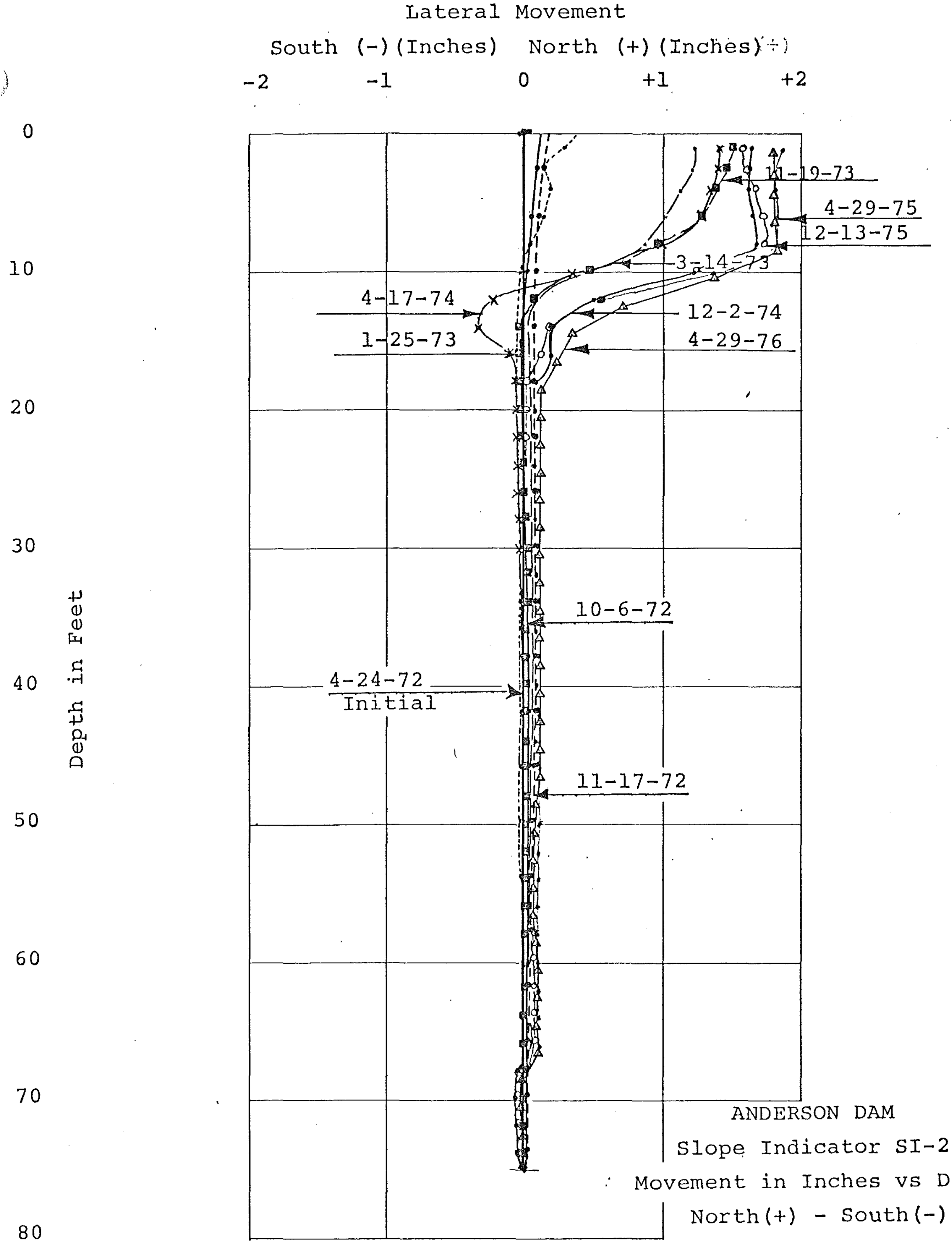
SLOPE INDICATOR DATA

PROJECT: ANDERSON RESERVIOR

SANTA CLARA COUNTY FLOOD CONTROL & WATER DISTRICT

OBSERVATION WELL NO. SI-2

Depth Ft.	Initial Diff.	E+	W-	Diff.	Change	Def'l. In.
1.0	7	571	534	37	30	.62
2.5	10	567	540	27	17	.49
4.0	7	571	543	28	21	.41
6.0	42	575	539	36	-6	.28
8.0	42	584	529	55	13	.32
10.0	42	584	532	52	10	.24
12.0	42	583	534	49	7	.18
14.0	41	580	536	44	3	.14
16.0	7	570	540	30	23	.12
18.0	3	563	550	13	10	-.01
20.0	1	560	553	7	6	-.07
22.0	-2	558	556	2	4	-.10
24.0	-2	553	562	-9	-7	-.13
26.0	1	553	560	-7	-8	-.09
28.0	1	557	557		-1	-.04
30.0	1	556	558	-2	-3	-.03
32.0		557	558	-1	-1	-.01
34.0	-2	557	559	-2		-.01
36.0	-28	551	563	-12	16	-.01
38.0	-26	542	572	-30	-4	-.10
40.0	-21	543	568	-25	-4	-.08
42.0	-20	545	566	-21	-1	-.06
44.0	-18	545	566	-21	-3	-.05
46.0	-11	549	566	-17	-6	-.03
48.0	-8	552	562	-10	-2	.00
50.0	-8	552	562	-10	-2	.01
52.0	-5	554	562	-8	-3	.02
54.0	-24	554	563	-9	15	.04
56.0	-20	544	565	-21	-1	-.04
58.0	-20	547	567	-20		-.04
60.0	-19	547	567	-20	-1	-.04
62.0	-13	550	563	-13		-.03
64.0	-16	552	563	-11	5	-.03
66.0	-2	554	566	-12	-10	-.06
68.0	-2	555	559	-4	-2	-.00
70.0	-3	556	558	-2	1	.00
72.0	-3	556	560	-4	-1	.00
74.0	-5	555	558	-3	2	.00



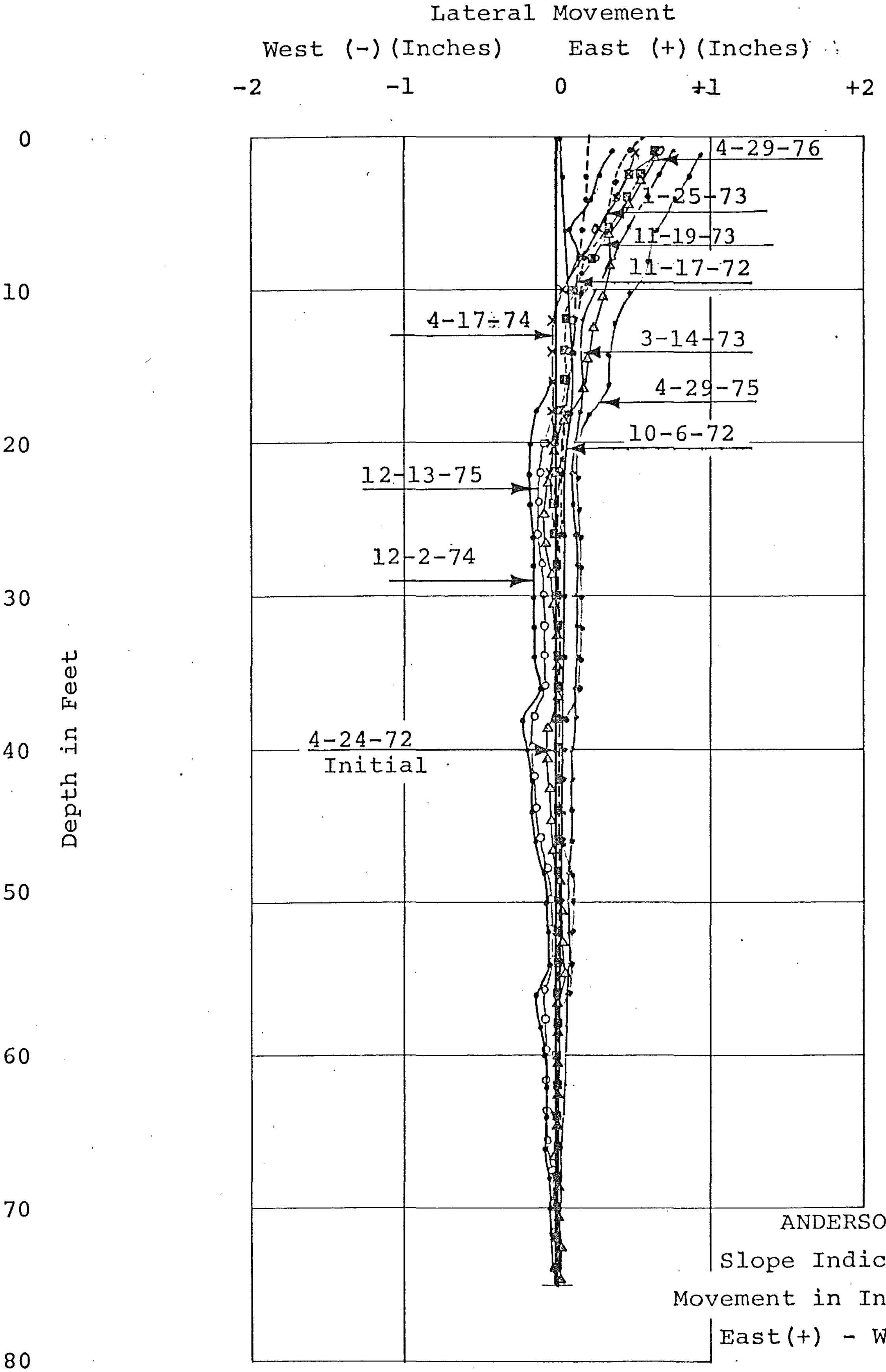
ANDERSON DAM

Slope Indicator SI-2

Movement in Inches vs Depth

North(+) - South(-)

FIG. 8



ANDERSON DAM

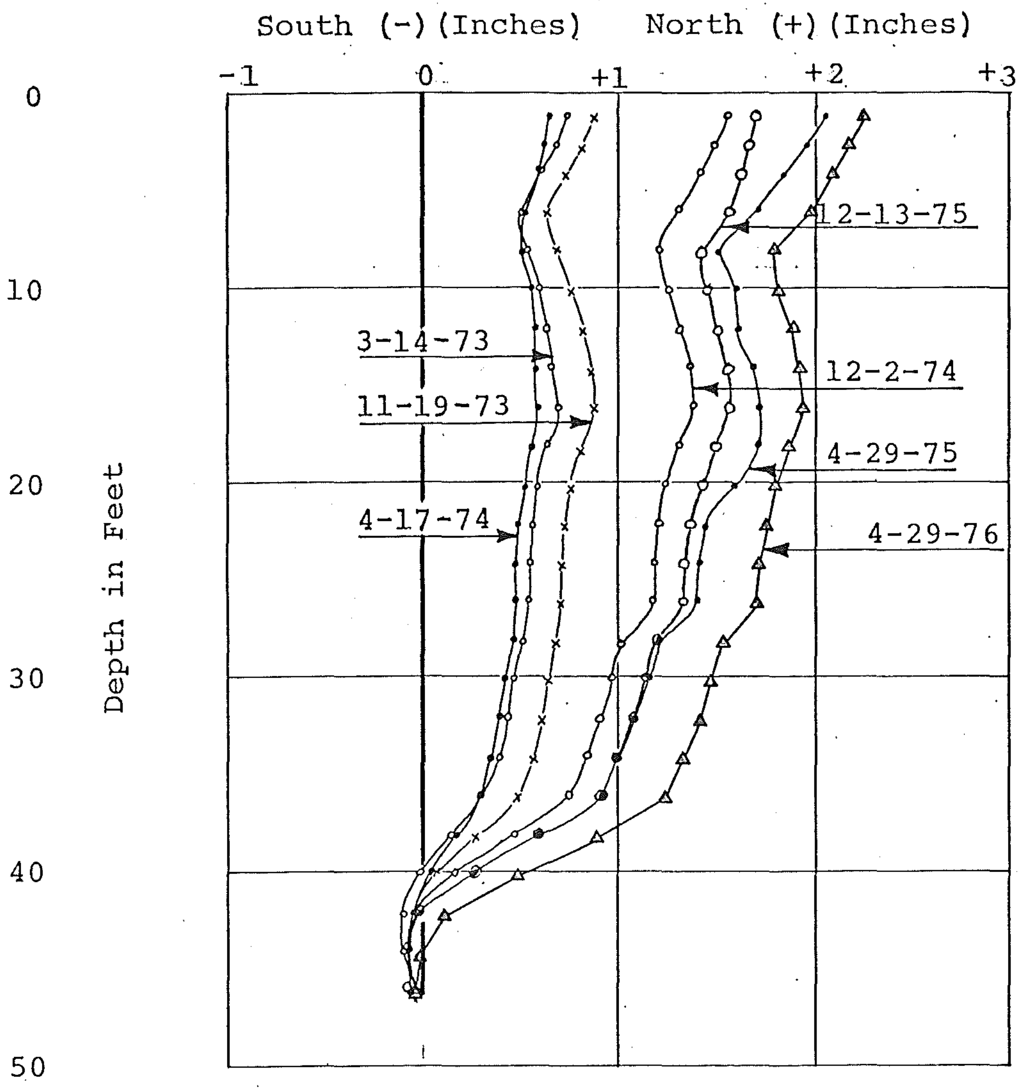
Slope Indicator SI-2

Movement in Inches vs Depth

East(+) - West(-)

FIG. 9

Lateral Movement Relative to the
46-Foot Depth



ANDERSON DAM
Slope Indicator SI-1A
Movement in Inches vs Depth
North (+) - South (-)

C-320 May '75

FIG. 10

SHANNON & WILSON, INC.
Geotechnical Consultants
1550 Rollins Road • Suite F • Burlingame, California 94010 • Telephone: (415) 697-7563

January 10, 1977

Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, CA 95113

Attention: Mr. Jim Scott

INCLINOMETER READINGS
ANDERSON DAM

At your request and in general accordance with your Purchase Order No. 13874, we have obtained a second set of readings for casing SI-3. This set of readings completes the work covered by the Purchase Order.

The initial readings were obtained on November 28, 1976, and were reported in our letter dated December 16, 1976. The current readings were obtained on January 4, 1977, at which time the reservoir was believed to be at about its minimum pool level for the current drawdown. The readings have been reduced and tabulated on Sheet 1 and 2 of 2 and plotted on Fig. 1 and 2. The data indicate minor apparent movement in the north and east directions (downhill) above depths of 20 and 15 feet, respectively.

Apparent displacements in the east direction below about 25 feet are generally within the instrument sensitivity of about one-inch per one hundred feet of casing and are probably not ground displacements.

Future readings will be necessary to determine whether the apparent displacements above 20 feet are due to casing adjustments or to ground movements. To minimize casing adjustments in the upper five feet of hole, it is recommended that the casing be backfilled completely to the surface with grout or fine sand.

At the time of the readings the water level was found to be at 4.5 feet below the top of the casing. We are available to obtain additional readings at your request. Please do not hesitate to contact us if you have any questions.

Rudy J Dietrich

Rudy J. Dietrich, P.E.
Senior Vice President

dmh

Enclosures: Slope Indicator Data

Sheet 1 of 2
Date of Reading
1-4-1977

SLOPE INDICATOR DATA

PROJECT: ANDERSON RESERVOIR

SANTA CLARA COUNTY FLOOD CONTROL & WATER DISTRICT

OBSERVATION WELL NO. SI-3

Depth Ft.	Initial Diff.	N (+)	S (-)	Diff.	Change	Def'l. In.
2.0	-151	470	623	-153	-2	.21
3.0	-160	467	630	-163	-3	.21
5.0	-159	474	634	-160	-1	.23
7.0	-164	472	638	-166	-2	.24
9.0	-164	473	638	-165	-1	.25
11.0	-151	482	630	-148	3	.25
13.0	-152	483	629	-146	6	.24
15.0	-144	487	624	-137	7	.20
17.0	-127	497	617	-120	7	.16
19.0	-111	504	609	-105	6	.12
21.0	-109	504	609	-105	4	.08
23.0	-112	501	611	-110	2	.06
25.0	-105	504	607	-103	2	.04
27.0	-104	506	606	-100	4	.03
29.0	-105	504	608	-104	1	.01
31.0	-118	497	616	-119	-1	.00
33.0	-132	492	620	-128	4	.01
35.0	-142	485	626	-141	1	-.01
37.0	-151	481	630	-149	2	-.01
39.0	-157	478	634	-156	1	-.03
41.0	-155	478	632	-154	1	-.03
43.0	-170	471	640	-169	1	-.04
45.0	-176	469	644	-175	1	-.04
47.0	-163	475	637	-162	1	-.05
49.0	-152	481	630	-149	3	-.06
51.0	-150	480	631	-151	-1	-.07
53.0	-137	487	624	-137		-.07
55.0	-130	491	622	-131	-1	-.07
57.0	-119	496	617	-121	-2	-.06
59.0	-117	498	616	-118	-1	-.05
61.0	-98	506	606	-100	-2	-.04
63.0	-96	507	606	-99	-3	-.03
65.0	-102	504	608	-104	-2	-.01
67.0	-103	504	608	-104	-1	-.00
69.0	-106	504	610	-106		.00
71.0	-119	497	616	-119		.00
73.0	-116	498	615	-117	-1	.00
75.0	-106	503	609	-106		.00
77.0	-97	509	604	-95	2	.00
79.0	-88	512	602	-90	-2	-.00
81.0	-77	518	594	-76	1	.00
83.0	-76	518	595	-77	-1	.00
85.0	-94	510	603	-93	1	.00
87.0	-104	504	608	-104		.00
89.0	-120	497	617	-120		.00
91.0	-144	484	628	-144		.00

Note: The casing slot designated North is true Northwest

Sheet 2 of 2
Date of Reading
1-4-1977

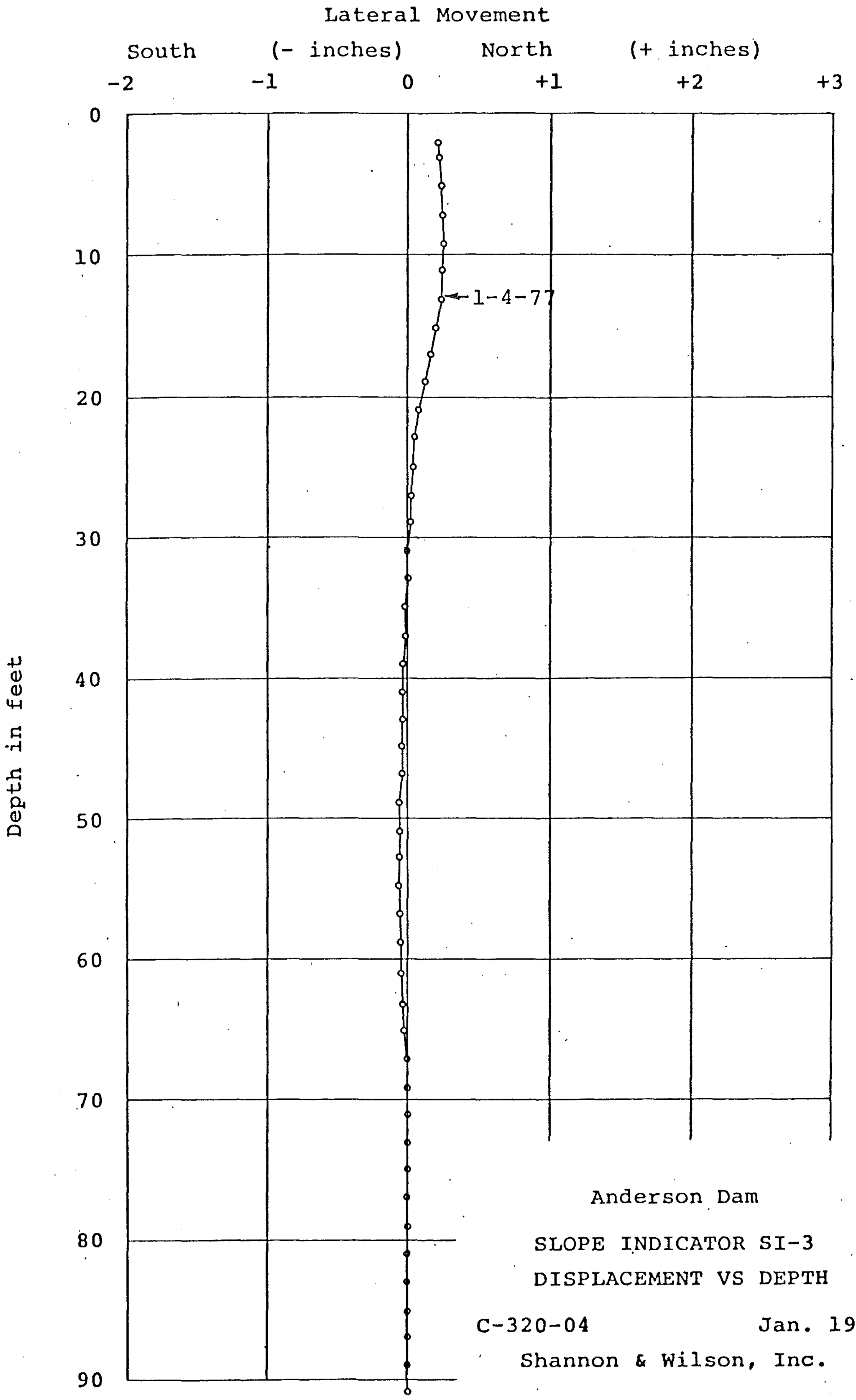
SLOPE INDICATOR DATA

PROJECT: ANDERSON RESERVOIR

SANTA CLARA COUNTY FLOOD CONTROL & WATER DISTRICT

OBSERVATION WELL NO. SI-3

Depth Ft.	Initial Diff.	E (+)	W (-)	Diff.	Change	Def'l. In.
2.0	95	590	505	85	-10	.32
3.0	101	596	503	93	-8	.35
5.0	97	597	509	88	-9	.40
7.0	88	598	512	86	-2	.45
9.0	84	600	511	89	5	.46
11.0	90	605	505	100	10	.43
13.0	84	604	507	97	13	.37
15.0	84	600	511	89	5	.30
17.0	85	598	513	85		.27
19.0	80	595	516	79	-1	.27
21.0	62	586	523	63	1	.27
23.0	87	602	508	94	7	.27
25.0	80	597	512	85	5	.22
27.0	74	593	516	77	3	.19
29.0	65	587	522	65		.18
31.0	52	582	529	53	1	.18
33.0	46	581	533	48	2	.17
35.0	34	572	538	34		.16
37.0	29	571	542	29		.16
39.0	22	565	543	22		.16
41.0	14	562	548	14		.16
43.0	-2	555	556	-1	1	.16
45.0	-17	548	562	-14	3	.15
47.0	-24	543	566	-23	1	.13
49.0	-27	542	567	-25	2	.13
51.0	-33	540	570	-30	3	.12
53.0	-41	535	576	-41		.10
55.0	-57	526	584	-58	-1	.10
57.0	-59	526	586	-60	-1	.10
59.0	-62	525	586	-61	1	.11
61.0	-75	517	592	-75		.10
63.0	-93	509	602	-93		.10
65.0	-98	508	603	-95	3	.10
67.0	-100	506	606	-100		.09
69.0	-106	502	608	-106		.09
71.0	-118	498	612	-114	4	.09
73.0	-89	512	600	-88	1	.06
75.0	-82	517	596	-79	3	.06
77.0	-77	517	592	-75	2	.04
79.0	-78	517	594	-77	1	.03
81.0	-73	517	592	-75	-2	.02
83.0	-85	514	597	-83	2	.03
85.0	-79	517	593	-76	3	.02
87.0	-77	517	592	-75	2	.00
89.0	-86	514	601	-87	-1	-.00
91.0	-95	508	603	-95		.00



Anderson Dam

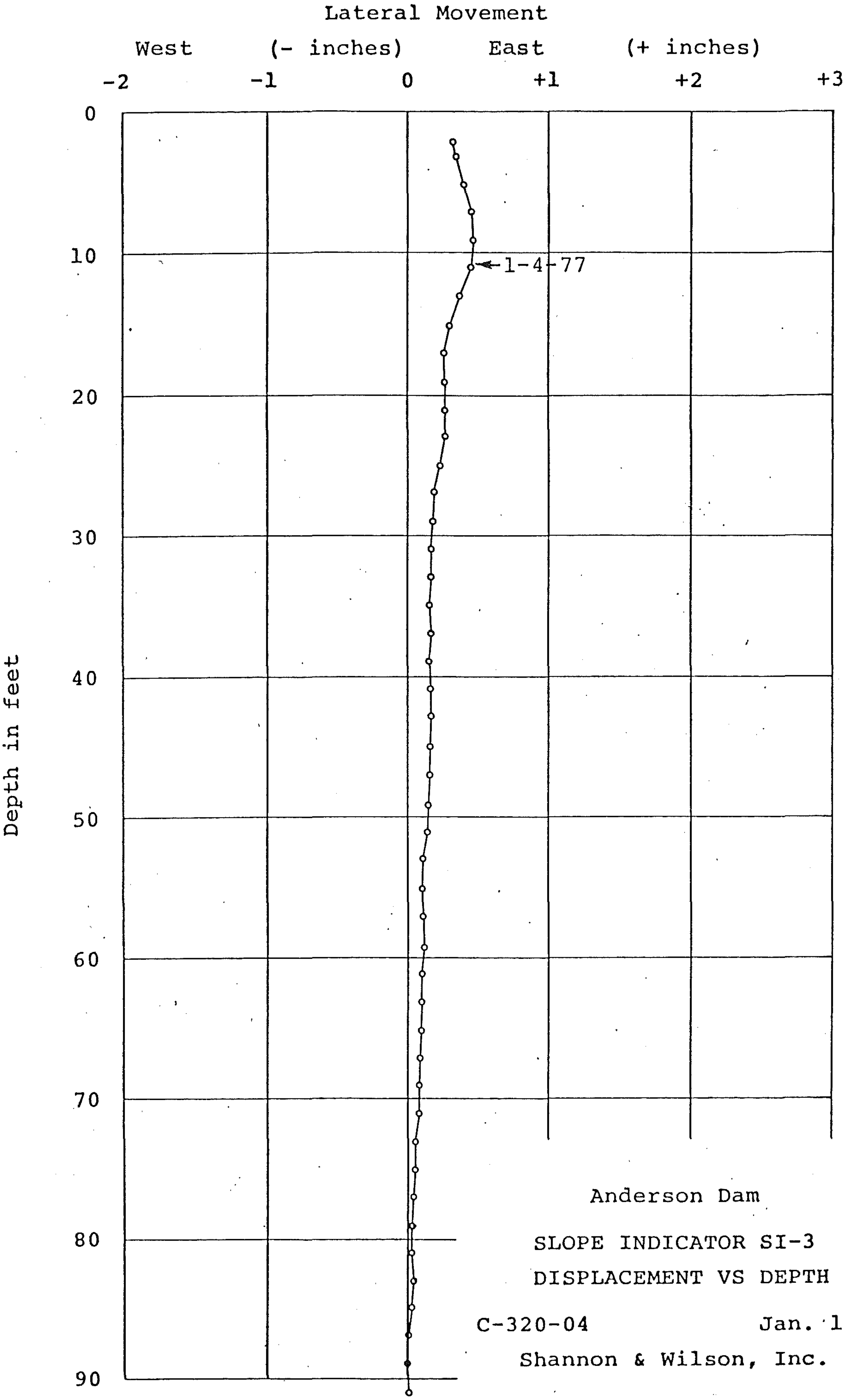
SLOPE INDICATOR SI-3

DISPLACEMENT VS DEPTH

C-320-04 Jan. 1977

Shannon & Wilson, Inc.

FIG. 1



Anderson Dam

SLOPE INDICATOR SI-3
DISPLACEMENT VS DEPTH

C-320-04 Jan. 1977
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FIG. 2

APPENDIX 3

GEOLOGIC AND SLOPE INDICATOR DATA ON THE LANDSLIDE AREA ON THE LEFT ABUTMENT OF ANDERSON DAM, BY FRANK W. FENZEL, JANUARY 16, 1974

Introduction:

This memorandum presents geologic and slope indicator data on the landslide area located on the left abutment of Anderson Dam. The purpose of this study is to evaluate conditions as they exist at present. The area is of concern to the District because of the potential problems that the landslide area poses to the inlet structure of the dam and to the Department of Parks and Recreation's boat launching ramp. Movement is now taking place and has been observed in the past. In 1962 movement occurred that damaged the boat launching ramp and some small structures. In 1969 movement occurred upslope of the 1962 movement necessitating moving the caretakers cottage. Because of the potential danger the landslide area presents, two slope indicators were installed in 1972.

A total of two half days was spent on the field investigation. Field examination revealed that the landslide area is a complex ancient slide with both active and inactive regions. The landslide has been subdivided into landslide "A", landslide area "B" and ancient landslide deposits.

Geologic Conditions:

The greenstone shown on the map (Figure 1) above the left abutment of Anderson Dam in which inclinometer hole SI-2 was drilled is highly weathered and fractured as are most Franciscan greenstones; however, this mass shows slickensides and evidence of shearing possibly reflecting ancient regional diastrophism of the mass and possible movement on the nearby Coyote Creek Fault. The trace of this fault was not exposed above the greenstone quarry, but was mapped in the field in the inferred position of the greenstone-serpentinite contact with greenstone occurring to the west and serpentinite occurring to the east of the fault. This location agrees fairly well with the projection of this fault to the southwest (approximately 1,000 feet from the reservoir) to a sag feature noted on the aerial photo. The projected trace of this fault was observed again approximately where the concrete boat launching ramp bends from southwest to south. There the fault was mapped at the contact between, possibly in place, greywacke to the east and sheared serpentinite to the west. This serpentinite may be in place or be part of a large block slide mass - - it is highly sheared and very soft, especially when wet. Like many serpentinite bodies it contains boulder size blocks of hard, competent serpentinite or periodotite. The mapped eastern portion of this serpentinite body forms the western boundary of the known active portion of landslide "A".

It is inferred that the above mentioned fault passes just upstream of the inlet structure (Figure ___) based on the authors interpretation of Marliave's geologic map (Figure____). On this map the fault is postulated to separate the serpentinite upstream from the sandstone downstream (the actual location of the inlet structure is not as shown on Marliave's map; personal communication with John Clark (December 1973) indicates that the inlet structure was moved downstream so that it would terminate in upstream compent sandstone rather than the originally proposed location in serpentinite which subsequent to excavation proved to be incompetent). The inferred fault contact between the sandstone and the serpentinite, if project uphill to the boat ramp, ties into the Coyote Creek Fault (Figure 1).

Landslide Deposits:

The landslide deposits were subdivided into landslide "A", landslide area "B", and ancient landslide deposits. The upper part of landslide "A" and landslide area "B" are considered reactivated portions of ancient landslide deposits. The lower portion of landslide "A" has an unaccessed potential for movement and may or may not be reactivated. The location of landslide "A", landslide area "B", and ancient landslide deposits is shown on Figure 3.

Because of vegetative cover, lack of outcrop, and submergence, the extent of the ancient landslide deposits could only be approximately determined. Ancient landslide deposits were observed in the eastern side scarp right flank and main scarp of active landslide "A" indicating that these deposits extend farther out than the boundary of active landslide "A". In the main scarp and the eastern side scarp of active landslide "A" ancient landslide deposits composed of serpentinitic material were observed. The boundary of ancient landslide deposits thus lies outside these two areas and was conjectured to lie slightly east of the eastern flank of the slide and upslope of the main scarp. The southwest boundary of the ancient landslide deposits is marked by a small amphitheatre-like area downslope from inplace serpentinite and east of the Coyote Creek Fault. Downslope and west of the Coyote Creek Fault the boundary was defined by the change in character of the greenstone material from definitely in place but fractured and slickensided greenstone on the west to apparently crushed greenstone derived materials on the east. The extent of the ancient landslide deposits below the reservoir level (approximately 600 feet at the time of this report) could not be determined but a photograph taken in 1962(?) suggests that they may extend from the hypothysized downslope edge of active landslide "A" to the bottom of the reservoir (see Figure___). The photograph taken in 1962 shows a difference in material at the bottom of the reservoir along the western boundary of landslide area "A". The material to the east appears much finer grained with no development of a prominent shear direction. This material may represent ancient landslide deposits. Upslope from this contact two cracks were observed in the finer grained material below the level of the boat ramp. The significance of these cracks can not at this time be ascertained because the elevation at which they occurred is below the present reservoir level but their possible significance should not be overlooked, i.e. they may indicate movement along a lower slip surface than is thought to operate along active landslide "A". For that reason lower conjectural slip surfaces are drawn on the profiles of landslide "A" (see Figures ____and_____). These slip surfaces encompass both the upper active portion and the lower portion with an unaccessed potential for movement of landslide "A". The serpentinite with the well developed shear direction described above may represent in place serpentinite or may represent a more competent mass within the inactive portion of the ancient landslide. This serpentinite mass may be continuous upslope to and with the possibly in place serpentinite mass described under geologic conditions.

The ancient landslide materials may thus occupy a region approximately 1000 feet long, 700 feet wide at the top and over 1000 feet wide at the toe, with a possible depth as shown by the lower conjectural slip surfaces as shown on the profiles for landslide "A", Figures ___and_____.

Landslide "A":

Active landslide "A" is a reactivated part of the ancient landslide mass previously described. The scarps of this slide are well defined and steep and can be seen on an aerial photo as well as in the field. The slide is comprised almost entirely of serpentinite derived materials of clay and pebble size with occasional rounded cobbles of serpentinite. As measured on the map (Figure____) and the landslide profiles Figures_____and______, the slide is 250 feet to 400 feet long and varies in width from 250 feet to 400 feet.

Before the construction of the dam the damsite was investigated by two consultants, Mr. Chester Marliave and Dr. George Louderbeck. Their reports mentioned landslide "A". In a geologic report dated September 15, 1949 Mr. Chester Marliave stated that: "Exposures of shale and sandstone occur all along the old road cut upstream from the concrete bridge.....Along the old road location beyond this fence there is first a 65 foot width of hard serpentine rock beyond which the formation is all soft weathered serpentine as far as the upper end of the gorge. In this soft serpentine area there are some extensive slides but they do not encroach upon the Franciscan sediments". Personal communication with John Clark (January 14, 1974) indicates that the road referred to is at the level of the outlet pipe and therefore near the bottom of the reservoir.

This soft serpentinite is interpreted as referring to the lower portion of landslide "A". Thus, the landslide deposits may extend to the bottom of the reservoir. In a letter dated June 5, 1950 Dr. George Louderbeck stated that: "In past time a large slide has occurred in the left canyon slope not far above the dam site. It is terminated upward by a striking cliff, which is at an elevation well above the top of the dam. The mass of serpentine that moved down the slope undoubtedly stopped in a condition of stability under the conditions then prevailing. Whether the sliding action was brought about as a result of an earthquake is not known. Future slumping from the steep cliff would dump material on the upper end of the slide with little chance of its directly reaching the reservoir. The present slide mass, if it did not come to rest under saturated condition, may, if its lower part becomes saturated with reservoir water, loose its stability and move down towards the canyon floor."

Comparison of air photos taken during 1960 and 1972 show damage to two roads. Aerial photographs for both years show failure of a road above the main scarp of active landslide "A" indicating movement in this area between the time the road was constructed (about the time the dam was constructed) and 1960. The aerial photograph for 1960 shows a road traversing the active slide approximately above the high water line; in 1972 the part of the road traversing the slide area was obliterated indicating movement in this area of the slide although the amount of movement cannot be determined.

During the spring of 1972 a 75 foot deep slope indicator SI-1A, was installed to accurately monitor the movement of active landslide "A". The location of slope indicator SI-1A is shown on Figure ____. The top of the slope indicator was surveyed in to detect if possible movement below the bottom of the hole in taking place. The results of the slope indicator monitoring program for slope indicator SI-1A are presented in Figures___and ____and the results of the surveying is presented in Figure_____. Slope indicator readings were taken on October 6, 1972; November 17, 1972; January 25, 1973; March 14, 1973 and November 19, 1973. On all but the last date, November 19, 1973, slope readings were obtained for the north-south and east-west directions--on November 19, 1973 inclinometer casing SI-1A was found to be so deformed by additional movement since the previous reading that the instrument would not proceed past a depth of 48.5 feet in the north and south slots. From the plots of the inclinometer survey readings it can be seen that most of the movement has taken place between 46 and 50 feet in the north, downslope, (not true north) direction. Between October 6, 1972 and January 25, 1973 the movement in the downslope direction was 0.7 inches; between January 25 and March 20, 1973 the movement was about 7 inches.

Figure_____presents the results of the two surface surveys. Comparing the closest time intervals for the inclinometer surveys (January 25, 1973, and March 20, 1973) and the surface surveys (December 25, 1972 and March 16, 1973) the surface survey showed 0.52 feet of movement (6.4 inches) while the inclinometer survey showed 7.3 inches of movement. Shannon and Wilson (March 20, 1973) suggest that the difference may be in the point of reference used; i.e. the survey data may be relative to the top of the protective cover in lieu of the plastic casing for the inclinometer. Comparison of these surveys indicate that all the surface movement of the inclinometer can be accounted for by the shear zone between 46 and 50 feet.

During the field survey, cracks and small scarps were noted along the periphery of the active landslide.

One crack, located in the upper southeastern part of the slide at an approximate elevation of 750 feet, measured 45 feet in length, 0.3 feet at the widest part, and a measurable depth down a piping funnel of 2 feet. The presence of piping funnels and rounding of the edges of the cracks suggest that they were present before the last rainy reason (1972-73). Downhill from the above cracks near the northeast side of the slide approximately at the lower edge of the vegetation and above the high water line, a small seep was noted.

Subsequent to field investigation approximate topographic profiles of landslide "A" were drawn. To accomplish this two different topographic base maps of very different scales were combined. From the combined topographic map two approximate profile sections were constructed down the profile of the slide. Profile section B-B' (Figure____) passes through slope indicator hole SI-1A and is drawn roughly parallel to the direction of slide movement. Using the data obtained from the inclinometer readings in hole SI-1A indicating a shear zone at a depth of approximately 50 feet and the head scarp of active landslide "A" an inferred slip surface for the active part of landslide "A" was drawn. If the hypothysized conditions are correct and accelerated movement of the mass should occur, then the slip plane would daylight above the boat ramp. The maximum depth of sliding indicated by the slope indicators is 75 feet (See Figure_____)- - if the actual slip surface is this deep then it would daylight in the vicinity of the boat ramp. However, this is not thought to be the case as the movement at this depth has been incremental when compared with that of the movement occurring at a depth of 50 feet (See Figure____).

Less information is available for Section C-C' than for B-B' (i.e., the section does not pass through an inclinometer hole). If the information from slope indicator SI-1A is project into the line of Section of C-C' (i.e., the depth of the slide plane) a conjectural slip surface can be hypothysized (see Figure____). If the hypothysized slip circle can be considered approximately correct, then the outlined slide would contain a greater volume of material than the hypothysized slide in Section B-B'.

Possible slip surfaces were also drawn for the lower portion of landslide "A", i.e. the portion with the unaccessed potential for movement (See Figures______and_______).

Using the approximate surface area of active landslide "A" as shown on the map (Figure____) of 140,000 square feet and an average depth of approximately 75 feet obtained from the landslide profiles, Figures_____and______, the volume of active landslide "A" is computed to be roughly 400,000 cubic yards. The depth of the slide is inferred from the profiles which incorporate the data from slope indicator SI-1A (Figures_____and____); however deeper slip planes may exist and the slide may extend to the bottom of the reservoir as discussed under "Ancient Landslide Deposits".

Active Landslide Area "B":

Active landslide area "B" includes an area in which active landslide movement has been observed in 1962, 1969, and 1972-73, and was recorded by slope indicator SI-2 for 1973. This area of landslides may be reactivated portions of the ancient landslide deposits previously described. This area of landslides if of importance to the District as it is located above the inlet structure of the dam.

Between March 7 and 17, 1962, a landslide developed on the reservoir slope above the inlet structure between the elevations of 500 and 600 feet (See Figure____). Information on this slide was obtained from a memo, "New Landslide at Anderson Reservoir" March 19, 1962, by E. Imhoff to J. R. Roll. The slide was about 200 feet across and 300 feet in the direction of flow. The depth was unknown but thought to exceed 50 feet. Total downward and outward separation at the head amount to 6 to 7 feet. The composition of the slide was described as fill material consisting of clay to cobble size particles of serpentine and altered igneous rock but could have been materials from the ancient landslide. The slide damaged the concrete boat launching ramp, a small amusement stand and slab, a gas pump, and a storage tank, and broke and contorted an asphalt road located at the head of the boat ramp. The slide also endangered four buildings upslope which were later removed.

On February 28, 1969 tension cracks were noticed in the driveway north of the caretakers home about 100 feet upslope of the main scarp of the landslide that occurred during March of 1962. Information for this slide was obtained from a memo, "Geologic Conditions at the Landslide Upstream of the South Abutment of Anderson Dam", March 26, 1969, from J. Wire to W. Roman. A geologic cross-section from this report is included as Figure_____. Between February 28th and March 11th potential slide mass was moving at the rate of 0.01 feet per day; after that date no further movement was observed. Total vertical displacement as of March 17, 1969 was 1/2 inch. It was thought that most of the slide mass was composed of fill or residual soil (possible ancient landslide deposits). Two resistivity soundings made on March 19, 1969 indicated that the thickness of the fill (or residual soil or possibly ancient landslide deposits) ranged from 15 feet behind the house to 40 feet closer to the reservoir. The log of nearby well 17-F-2 indicates a depth of 60 feet to bedrock. It was thought that the cessation of movement was the result of a dissipation of hydrostatic head during a period of no rainfall and allowing the nearby well to flow unrestricted. When the well was drilled the first water was encountered at 40 feet and rose to 25 feet indicating confined conditions. As a result of the movement the caretakers cottage was removed and relocated.

In a memo from J. Vantine to Jack Watkins, Jr., "Results of Monitoring and Geologic Findings of the Landslide Area on the Left Abutment of Anderson Dam", dated April 26, 1973 two areas of additional scarps and signs of failure were described. The first area is located 50 feet to the east and southeast of slope indicator SI-2 which was installed in slide area "B". The small scarps were thought to be a few years old and to have occurred during the failure reported in 1969. The uppermost scarp was reported to be 2 feet deep and 8 to 12 inches wide. A 2 foot deep, parallel semi-circular scarp was reported about 12 feet downslope from the uppermost scarp. During the winter of 1972-73 a shallow landslide was reported to have formed extending from the boat ramp upslope to just below slope indicator SI-2. The head of the slide occurs between 5 to 10 feet downslope of the road the slope indicator is located on. The dimensions of the slide were reported as about 80 feet long, 47 feet wide in the middle with a minimum estimated depth of 15 feet and a maximum estimated depth of 25 feet. Scarps along the flanks of the slide were reported as being 3 and 4 feet in depth.

During the field investigation for this report this slide measured about 60 feet wide in the central portion and the side and head scarps were about 4 to 6 feet deep.

During April of 1972 slope indicator SI-2 was installed a little upslope and slightly west of the landslide that occurred during the winter of 1972-73, 50 feet northwest and downslope of the small scarps reported to have possibly formed in 1969, and near the area where the failure cracks occurred during March of 1969. Slope indicator measurements were made on June 10, 1972; November 17, 1972; January 25, 1973; March 14, 1973 and November 19, 1973. Plots of these data are presented in Figures____and_____. As of November 19, 1973 slope indicator SI-2 has shown 1.5 and 0.7 inch of total movement in the north (downslope) and east directions respectively. Most of this movement took place between January and March of 1973. The depth of movement is shallow, between 10 to 12 feet.

The top of the slope indicator was surveyed on December 27, 1972; March 16, 1973 and April 10, 1973. The results of these surveys are presented in Figure______. During the time interval December 27, 1972 and April 10, 1973, downslope movement of 0.07 feet was measured.

Conclusions:

1. A complex ancient landslide occurs on the left abutment of Anderson Dam.

2. The landslide deposits were subdivided into landslide "A", landslide area "B" and ancient landslide deposits.

3. Landslide area "B" and the upper part of landslide "A" are active reactivated portions of the ancient landslide deposits.

4. The lower portion of landslide "A" has an unaccessed potential for movement and extends to the bottom of the reservoir.

5. The slope indicators and surficial features indicate that both active landslide "A" and parts of active landslide area "B" are moving today - - based on previous inclinometer readings, this movement may be expected to be greater during the wet season.

6. The landslide areas pose a potential threat to the inlet structure of the dam and to the Department of Parks and Recreation's boat launching ramp.

Recommendations:

The following measures are recommended:

1. It is known that portions of the landslide are moving and therefore these portions should be monitored by continuing the inclinometer and surface survey programs.

2. Install and monitor an additional surface survey monument to be located along profile section C-C' at the same elevation as slope indicator SI-1A to monitor movements in the northeast upper active portion of landslide "A".

3. Periodic examination of the slide by field inspection for evidence of recent or active movements be conducted.

4. Activity of the bottom portion of landslide "A" is not known, but it is important to know what the bottom portion is doing as active movement in this part of the slide may have dire consequences on the inlet structure and the turbidity of the water passing out of the reservoir. Therefore, periodic examination of the concrete boat ramp for cracks or offsets that may indicate deep slide motion should be performed and a survey monument should be installed below the elevation of the concrete boat ramp to monitor possible deep slide movement. The lower end of the concrete boat ramp occurs at an elevation of 556.44 feet, therefore the survey monument should be installed at about an elevation of 550 feet. Records of previous reservoir surface elevations (Figure______) indicate that the water level during some years

drops below the 550 foot elevation, although no probability of this event occurring is assigned.

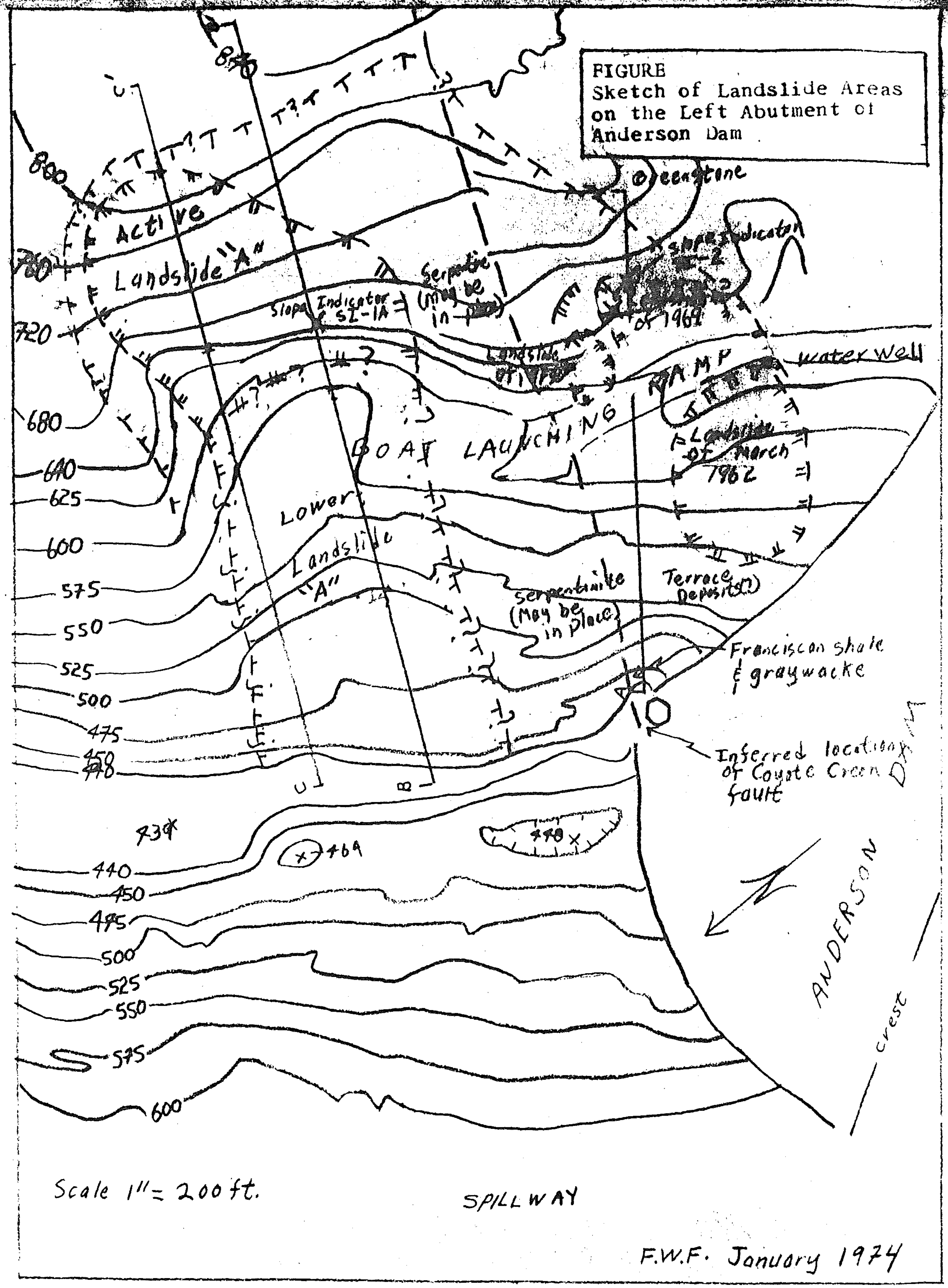


FIGURE
Sketch of Landslide Areas on the Left Abutment of Anderson Dam

Scale 1" = 200 ft.

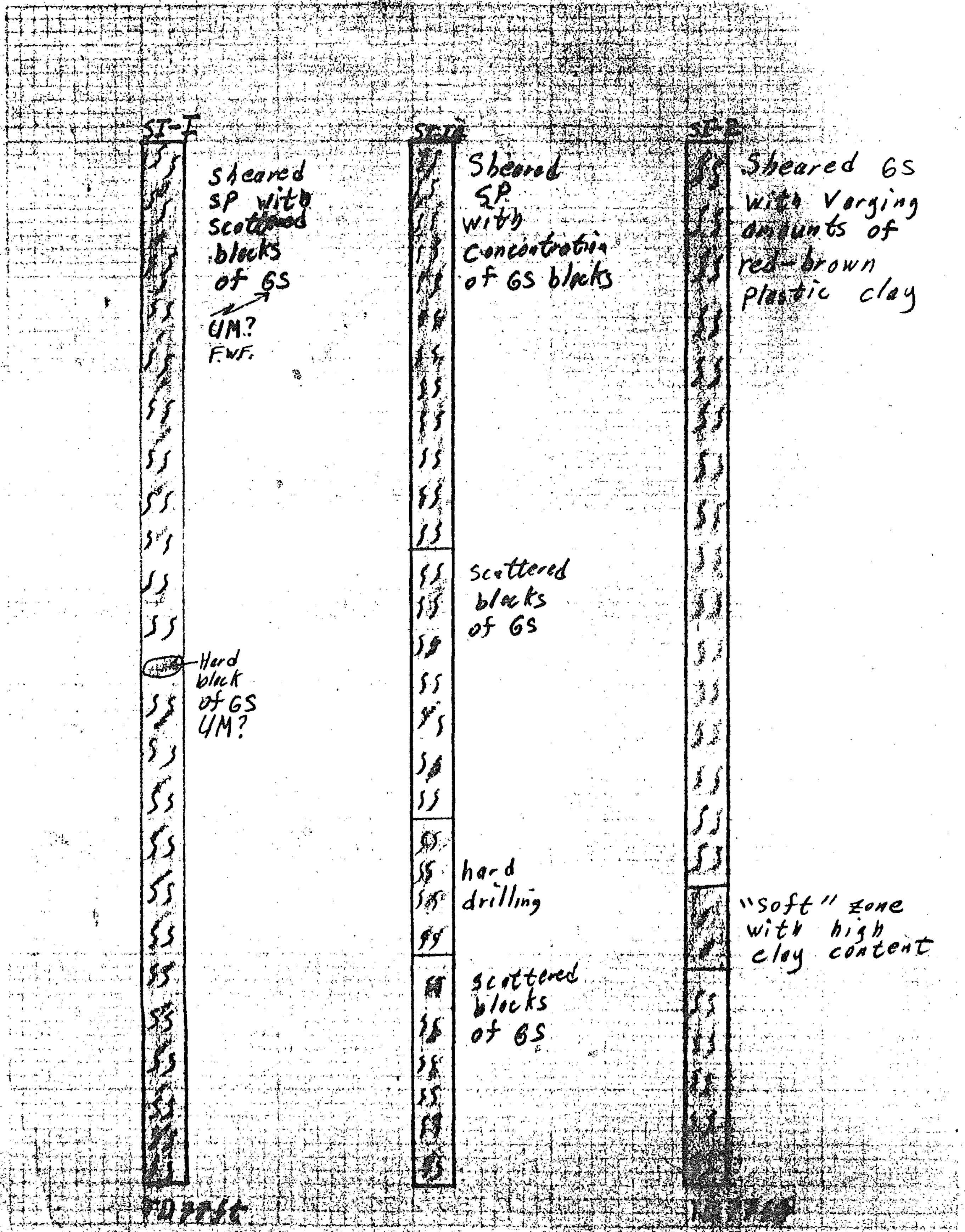
SPILLWAY

F.W.F. January 1974

By F.W.F. Date 13/Dec/[illegible] Chkd By ______ Date ______ Sheet No. ______ of ______

Subject Log at Inclinometer Holes Job No. Figure 5

Left abutment, Anderson Dam; Loged by S & W



ST-I
Sheared SP with ~~scattered~~ blocks of GS
UM?
F.W.F.
Hard block of GS UM?
ST-II
Sheared SP with concentration of GS blocks
scattered blocks of GS
hard drilling
scattered blocks of GS
ST-3
Sheared GS with varying amounts of red-brown plastic clay
"soft" zone with high clay content